Section/division **Accident and Incident Investigations Division** Form Number: CA 12-12c

HELICOPTER ACCIDENT REPORT AND EXECUTIVE SUMMARY

		Reference:		**CA18/2/3/9946**	
Helicopter Registration	**ZT-RRT**	**Date of Accident**	21 January 2021	**Time of Accident**	1118Z
Type of Helicopter	BELL 430		**Type of Operation**	Commercial (Part 138)	
Pilot-in-command Licence Type	CPL(H)	**Age**	40	**Licence Valid**	Yes
Pilot-in-command Flying Experience	**Total Flying Hours**	2680.3		**Hours on Type**	561.7
Last Point of Departure	Ultimate Heli, Midrand, Gauteng Province				
Next Point of Intended Landing	Hillcrest Hospital, Pietermaritzburg, KwaZulu-Natal Province				
Damage to Helicopter (Minor/Substantial/Destroyed)	Destroyed				
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)					
8nm north-east of Winterton at GPS coordinates S28° 46' 52.66" E29° 40' 28.09";m Elevation at 3301 feet (ft)					
Meteorological Information	Surface wind 260° at 04kts; Temperature 29°C; Dew point 18°C; Visibility 9999m; Nil cloud; QNH 1020				

Number of People On-board	1+1+3	**Number of People Injured**	0	**Number of People Killed**	5	**Other (On Ground)**	0

Synopsis

On 21 January 2021, a medical helicopter departed Ultimate Heli heliport in Midrand, Gauteng Province, at 0948Z with five occupants on-board (a pilot, a helicopter paramedic, two medical doctors and a theatre nurse) to collect a patient from Hillcrest Hospital in Pietermaritzburg, KwaZulu-Natal. According to Spidertracks (a device which monitors and reports to base the helicopter's velocity and height) the helicopter was cruising at an average height of 725 feet (ft) above ground level (AGL) and at a speed of 135 miles per hour (mph) in a south-easterly direction along the N3 Highway leading to Pietermaritzburg. The helicopter had 02h30min fuel endurance on-board and the weight and balance was within limits.

The Spidertracks was sending position reports every two minutes; the last data received was position 361 at a height of 725' AGL, cruising at 132mph. A few seconds later (after the data was received) the helicopter was seen by eyewitnesses on the N3 Highway near Winterton off ramp, as well as by another eyewitness on the farm located south-west of the helicopter's route (at the time). One eyewitness stated that he saw *white-like smoke coming from the top of the helicopter and that the helicopter was spinning and losing height; thereafter, the helicopter flew over the main road*, *impacted the ground, and was destroyed by post-impact fire*. All occupants were fatally injured. The wreckage distribution stretched for 500m, including across the main road. Before the helicopter impacted the ground, some major components (tail boom, windshield, tail rotor) were severed in-flight and fell at different points. The main rotor blades, which caused most of the damage, had broken off from the helicopter's main rotor mast and (the blades) were found at different positions (from the main wreckage). Post-accident examination indicated a fatigue crack on the threaded part of the clevis which had occurred during the life limit of the component.

Probable Causes

The clevis on the pitch control lever of the Orange blade failed in-flight, resulting in the instability of the main rotor disc which, in turn, severed the (most) rear section of the tail boom. As a result, the main rotor blades subsequently failed. The combination of the severed most rear section of the tail boom and the main rotor failure resulted in the pilot losing control of the helicopter and, thus, the subsequent crash.
Corrosion fatigue/metal fatigue, mechanical failure and improper maintenance.

Contributing factors:

Failure to identify the fatigue crack on the threaded section of the clevis during a magnetic particle inspection as well as during the mandatory periodic inspection (MPI).

SRP Date	8 February 2022	Publication Date	18 February 2022

INTRODUCTION

Reference Number	**:** CA18/2/3/9946
Name of Owner/Operator	**:** National Airways Corporation (Pty) Ltd
Manufacturer	**:** Bell Helicopter Textron
Model	**:** Bell 430
Nationality	**:** South African
Registration Marks	**:** ZT-RRT
Place	**:** Winterton
Date	**:** 21 January 2021
Time	**:** 1118Z

Purpose of the Investigation:

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011, this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and ***not to apportion blame or liability****.*

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Investigation Process:

The accident was notified to the Accident and Incident Investigations Division (AIID) on 21 January 2021 at about 1320Z. The investigator/s dispatched to Winterton on 22 January 2021 to conduct an on-site (full scope) investigation. The investigator/s co-ordinated with all authorities on site by initiating the accident investigation process according to CAR Part 12 and investigation procedures. The AIID is leading the investigation as the Republic of South Africa is the State of Occurrence.

Notes:
1. Whenever the following words are mentioned in this report, they shall mean the following:

- *Accident — this investigated accident*
- *Helicopter — the Bell 430 involved in this accident*
- *Investigation — the investigation into the circumstances of this accident*
- *Pilot — the pilot involved in this accident*
- *Report — this accident report*

2. Photos and figures used in this report were taken from different sources and may have been adjusted from the original for the sole purpose of improving clarity of the report. Modifications to images used in this report were limited to cropping, magnification, file compression; or enhancement of colour, brightness, contrast; or addition of text boxes, arrows or lines.

Disclaimer:

This report is produced without prejudice to the rights of the AIID, which are reserved.

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ABBREVIATION	DESCRIPTION
°C	Degrees Celsius
A/F	Airframe Hours
AGL	Above Ground Level
AMO	Aircraft Maintenance Organisation
AMSL	Above Mean Sea Level
AOC	Air Operating Certificate
C of A	Certificate of Airworthiness
C of R	Certificate of Registration
CAR	Civil Aviation Regulation
CPL	Commercial Pilot Licence
CVR	Cockpit Voice Recorder
FDR	Flight Data Recorder
ft.	Feet
GPIAA	Aircraft Accident Investigation Authority of Angola
GPS	Global Positioning System
HE	Hydrogen Embrittlement
hPa	Hectopascals
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Condition
kts	Knots
l	Litre(s)
m	Metre(s)
MHz	Megahertz
mm	Millimetres
MPI	Mandatory Periodic Inspection
MPI	Magnetic Particle Inspection
NAC	National Airways Corporation
NM	Nautical Mile
PCL	Pitch Control Lever
POH	Pilot's Operating Handbook
PPL	Private Pilot Licence
SACAA	South African Civil Aviation Authority
SAWS	South African Weather Service
SCC	Stress Corrosion Cracking
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Condition

1. FACTUAL INFORMATION

1.1. History of Flight

1.1.1 On Thursday, 21 January 2021, a pilot and four passengers on-board a Bell 430 helicopter with registration mark ZT-RRT were on an emergency flight from Ultimate Heli heliport in Midrand, Gauteng province, to Hillcrest Hospital in Pietermaritzburg, KwaZulu-Natal province. The flight was conducted under visual flight rules (VFR) by day and in accordance with (IAW) Part 127 endorsed in Part 138 of the Civil Aviation Regulations (CAR) 2011 as amended. The intention of the flight was to collect a patient from Hillcrest Hospital in KwaZulu-Natal province to Milpark Hospital in Gauteng province to receive specialised care/procedure which was unavailable at Hillcrest Hospital. A pilot, a helicopter paramedic, two medical doctors and a theatre nurse were on-board the helicopter. The two medical doctors and a nurse were from Milpark Hospital in Johannesburg; they were transported by road (in an ambulance) to Ultimate Heli heliport, from where they boarded the helicopter. The medical team had with them a total of 12 oxygen bottles, each weighing 6.86kg (total 82.32kg) and each with a capacity of approximately 20 minutes. The oxygen bottles were to be used by the patient whilst in-transit to the destined hospital.

1.1.2 The pilot performed a pre-flight inspection and gave his passengers a safety briefing. According to their standard operating procedure (SOP), the pilot would have to contact Grand Central Airport (FAGC), which is located 1.4 nautical miles (nm) north-east of the heliport to advise them of their flight requirements, that is, their intended route, persons on-board, fuel endurance and the required height. FAGC would then clear them for their required flight if there was no conflicting traffic; this procedure was adhered to. Once airborne and established on their flight, the pilot would then broadcast his intention on Johannesburg Special Rules. As soon as the helicopter reaches the Johannesburg Special Rules South boundary, the pilot would then change frequency from 125.4-Megahertz (MHz) to 123.4MHz and broadcast his position and level to alert other aircraft in the area en route; thereafter, continue with the flight as planned.

The helicopter was fitted with a Spidertracks device *(a small device that plugs into an aircraft's auxiliary power outlet and is mounted in the cockpit. It provides information such as location, altitude, speed and direction of the aircraft).* This device allows owners of aircraft to keep track of their helicopters by receiving updates every 2 minutes. According to the Spidertracks device, the helicopter took off at 0948Z and proceeded in a south-easterly direction, flying past Johannesburg Special Rules South boundary at approximately 1006Z at 725 feet (ft) above ground level (AGL). The helicopter was being flown at an average speed of 134 miles per hour (mph) and it remained approximately 700ft AGL.

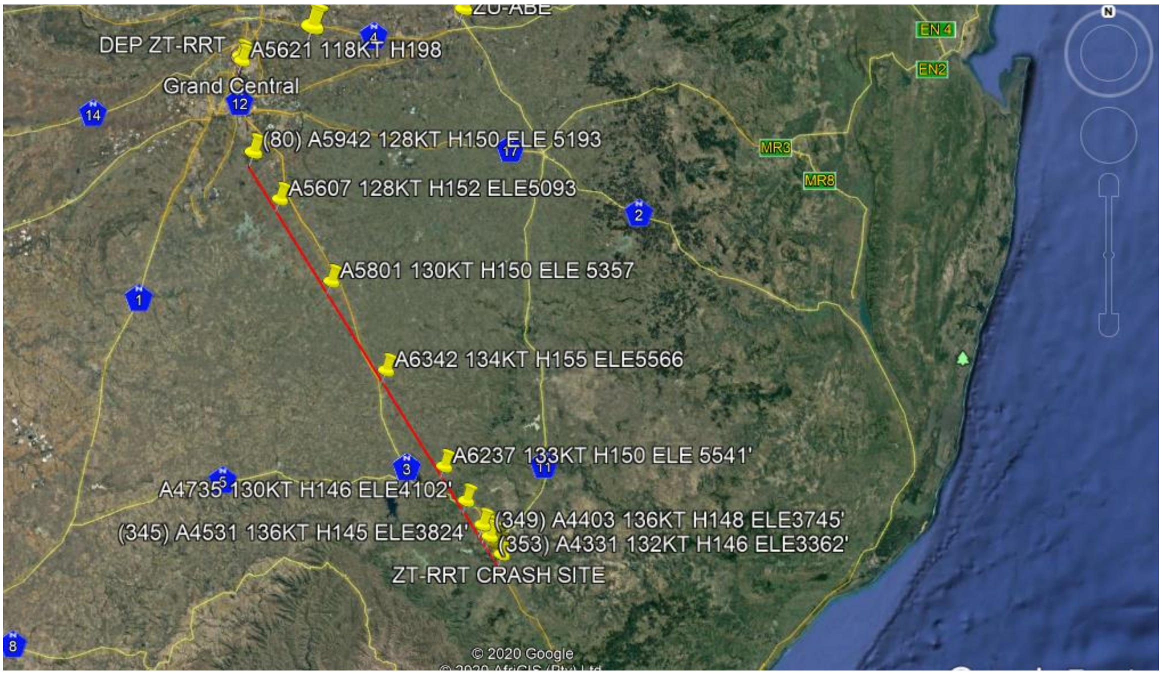


Figure 1: The flight path taken by ZT-RRT helicopter before the crash. (Source. Google Earth)

1.1.3 Eyewitnesses who were travelling on the N3 Highway as well as a farmer who was located on the south-west of the flight path observed the following: *the helicopter was seen spinning around whilst losing height rapidly. Thereafter, they observed what looked like helicopter parts breaking off of the helicopter before it impacted the ground and burst into flames.* This was about 2.45nm from the last Spidertracks reported position. This position is in the south-east of the helicopter's intended route. Debris from the helicopter was scattered along this path. The accident site stretched for approximately 500m from the first located object of the main wreckage. The helicopter was destroyed by post-impact fire whilst the pilot and four passengers were fatally injured.

1.1.4 The accident occurred during day light at Global Positioning System (GPS) co-ordinates determined to be S28° 46' 52.66" E29° 40' 28.09" at an elevation of approximately 3301 feet (ft).

1.2. Injuries to Persons

Injuries	Pilot	Crew	Pass.	Total On-board	Other
Fatal	1	1	3	5	-
Serious	-	-	-	-	-
Minor	-	-	-	-	-
None	-	-	-	-	-
Total	1	1	3	5	-

Note: Other means people on ground.

1.3. Damage to Helicopter

1.3.1 The helicopter was destroyed.

Figure 2: The helicopter's main wreckage at the site.

1.4. Other Damage

1.4.1 None.

1.5. Personnel Information

Nationality	South African	Gender	Male	Age	40
Licence Number	0271070591	Licence Type	CPL(H)		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Night rating, sling load, winching, MEL, SEL				
Medical Expiry Date	30 June 2021				
Restrictions	None				
Previous Accidents	ZS-RBL Bell 407 helicopter tail rotor strike at Milpark Hospital helipad on 27 December 2019.				

Note: Previous accidents refer to past accidents the pilot was involved in, when relevant to this accident.

Total Hours	2680.3
Total Past 24 Hours	1.5
Total Past 7 Days	8.3
Total Past 90 Days	53.4
Total on Type Past 90 Days	37.8
Total on Type	563.2

1.5.1 The pilot was initially issued a Commercial Pilot Licence (CPL) on 30 October 2009. He started working for National Airways Corporation (NAC) in 2010. Under his licence, the pilot had flown R22, R44 and a wide range of Bell Helicopters, namely: B205, B206, B206L, B407 and B430. The pilot had a total of 2680.3 hours of which 991.9 hours were on twin-engine helicopters. At the time of the accident, he was the pilot-in-command on a B430 and had completed certificate courses (stated below). His last CPL validation was on 25 November 2020 with an expiry date of 30 November 2021. The pilot was issued a Class 1 aviation medical certificate on 26 June 2020 with an expiry date of 30 June 2021. The pilot had also completed the following work safety-related certificate courses and satisfied the minimum flying requirements to command this flight as per NAC base operating procedure (BOP):

i. 1 000 Total Pilot-in-command (PIC) Hours

ii. 25 PIC Hours on the B206L / B407 / B430

iii. 25 PIC Night Hours

iv. 250 Turbine Hours

- A Part 138 Flight Crew Training programme for air ambulance services on 25 June 2020 with an expiry date of 31 June 2021.
- Dangerous Goods Awareness Category 10 programme on 21 October 2019 with an expiry date of 31 October 2021.
- Crew Resource Management (CRM) refresher course on 9 October 2020 with an expiry date of 31 October 2021.
- Annual company proficiency checks on 31 July 2020.

1.5.2 The helicopter paramedic was a qualified Emergency Care Practitioner (ECP). He had assisted the pilot in preparing the patient area in the helicopter before take-off. He had also completed the Flight Crew Training programme for air ambulance services on 18 May 2020 with an expiry date of 31 May 2021.

1.6. Aircraft Information

Airframe:

Manufacturer/Model	Bell 430	
Serial Number	49126	
Manufacturer	Bell Helicopter Textron	
Date of Manufacture	2005	
Total Airframe Hours (At Time of Accident)	7687.7	
Last MPI (Date & Hours)	23/09/2020	7546.6
Hours Since Last 150 MPI	141.1	
C of A (Issue Date)	23/06/2020	
C of A Expiry Date	30/06/2021	
C of R (Issue Date) (Present Owner)	22/11/2019	
Type of Fuel Used in the Helicopter	Jet A1	
Previous Accidents	On 15 November 2013 at 0930Z, the ZT-RRT helicopter, bearing Angolan registration mark D2-EYS, was involved in a serious incident in Angola whilst carrying eight people on-board.	

Note: Previous accidents refer to past accidents the helicopter was involved in, when relevant to this accident.

History of the Aircraft

1.6.1 Heli Malongo is an aircraft operator in Angola, eastern Africa, that operates helicopters for offshore operations in Angola. One of the helicopters was a Bell 430 manufactured by Bell Helicopter Textron of the United States of America (USA). The helicopter arrived from the USA with the registration N430JA on 6 November 2006. The N430JA was deregistered and given Angolan registration numbers after satisfying the Angolan Civil Aviation Regulations and airworthiness requirements. The new registration was D2-EYS. Thereafter, the helicopter started being used for commercial operation under Part 127, carrying passengers. According to Aircraft Accident Investigation Authority of Angola (GPIAA), on 15 November 2013 at 0930Z, the D2-EYS helicopter was involved in a serious incident whilst carrying eight (8) people on-board during approach for landing at the Cabinda Airport (north of Angola), after the offshore flight from the petroleum platform "Block 14" in Cabinda. None of the people sustained injuries during this incident, but the helicopter sustained substantial damage. The probable cause of this serious incident was "engine failure in-flight".

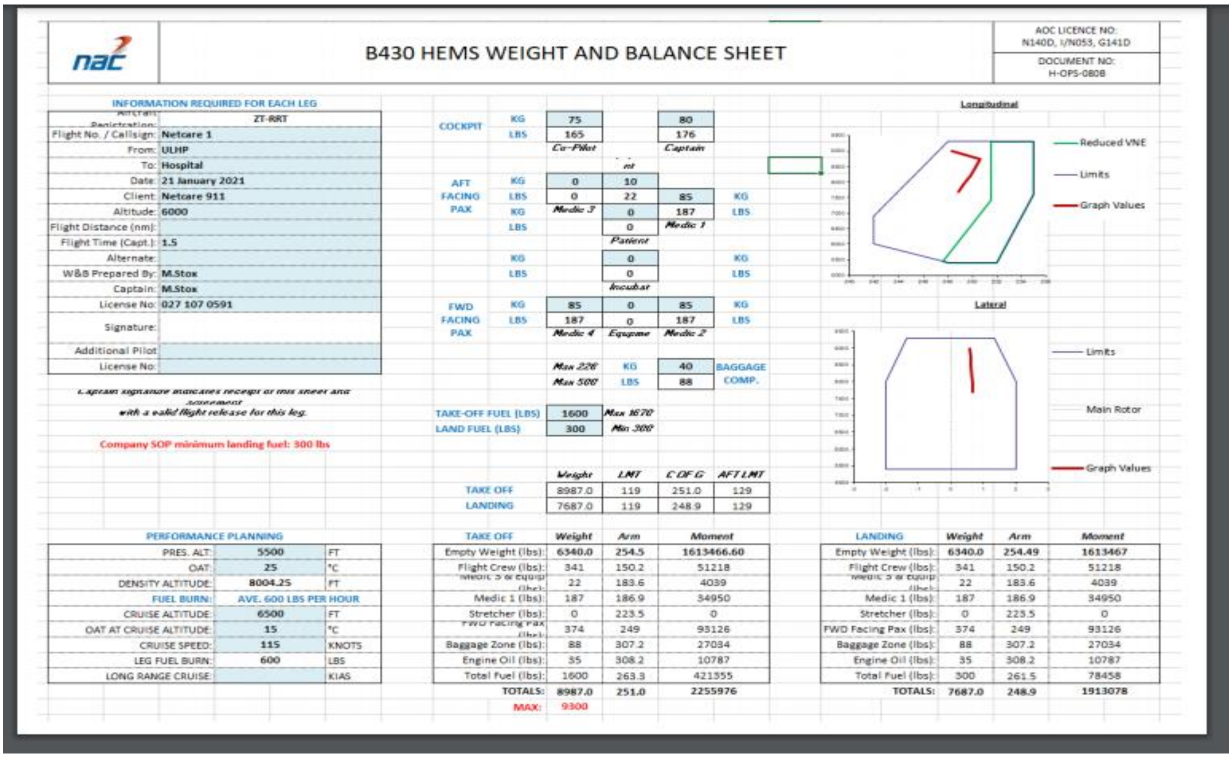
1.6.2 In November 2018, three Bell helicopters were de-registered in Angola and, during the following year (2019), they were acquired by the National Aircraft Corporation (NAC) in South Africa to be used in emergency medical transportation. In November 2019, the helicopters were disassembled, loaded/packed in containers, and shipped to South Africa with valid export Certificates of Airworthiness (CoA).

1.6.3 Between November 2018 and November 2019, the three helicopters were kept in a storage (facility) programme, which meant that they were not being operated but were kept airworthy by following the airframe and engine manufacturer's instructions, BHT 430 MM CH 10-18, which states that *aircraft must be defueled/purged with air and interior tanks fogged; preservative oil (1010) sprayed under all cowlings for corrosive prevention*. *Preservation tags and desiccant bags must be placed in engine bay areas (Annexure C).*

1.6.4 All three helicopters were assembled by the aircraft maintenance organisation (AMO) 1266. The three helicopters started operating after all applicable and necessary South African aviation regulations technical documents, manuals and commercial air certificate requirements were met. D2-EYS was re-registered as ZT-RRT and was given the call sign NETCARE 1. The Air Operating Certificate (AoC) needed for the helicopter to operate in Part 138, medical emergency, belongs to NAC, as well as all the helicopters that they operate. Netcare 911 is a client to NAC which contracts helicopters to transport their (Netcare) patients to different destinations around the country at a moment's notice.

1.6.5 All three helicopters were modified and fitted with Emergency Medical Services (EMS) equipment in accordance with Air Methods Corporation STC: SR00514DE-D on 29 June 2020. Another modification was the Articulate Patient Loading System (APLS) with STC: SR00235DE-D on 29 June 2020, ZT-RRT was at 7393.7 hours total time since new (TTSN).

1.6.6 According to the weight and balance, the helicopter seating arrangement was as follows: the pilot and the helicopter paramedic were seated at the front seats, and the two medical doctors and theatre nurse were seated at the back seats. The 12 full oxygen bottles were strapped down on the patients' bed using the bed straps. The helicopter had 1600 pounds (lb) of Jet A1 fuel, with fuel consumption of 600 pounds per hour (lb/h). This meant that this flight had fuel endurance of 2 hours and 30 minutes. The maximum take-off weight of the helicopter is 9300lb. The ZT-RRT helicopter take-off weight was 8987lb, just 313lb below all-up weight. The helicopter was airborne for approximately 1.5 hours and fuel consumed was about 900lb, which gave an estimated weight of 8 087lb at the time of the accident.



B430 HEMS WEIGHT AND BALANCE SHEET

AOC LICENCE NO: N140D, I/N053, G141D
DOCUMENT NO: H-OPS-080B

INFORMATION REQUIRED FOR EACH LEG

Aircraft Registration:	ZT-RRT
Flight No. / Callsign:	Netcare 1
From:	ULHP
To:	Hospital
Date:	21 January 2021
Client:	Netcare 911
Altitude:	6000
Flight Distance (nm):	
Flight Time (Capt.):	1.5
Alternate:	
W&B Prepared By:	M.Stox
Captain:	M.Stox
License No:	027 107 0591
Signature:	
Additional Pilot	
License No:	

Captain signature indicates receipt of this sheet and agreement with a valid flight release for this leg.

Company SOP minimum landing fuel: 300 lbs

COCKPIT: Co-Pilot 75 KG / 165 LBS; Captain 80 KG / 176 LBS

AFT FACING PAX: Medic 3 0 KG / 0 LBS; 10 KG / 22 LBS; Medic 1 85 KG / 187 LBS; Patient 0 KG / 0 LBS; Incubator 0 KG / 0 LBS

FWD FACING PAX: Medic 4 85 KG / 187 LBS; Equipment 0 KG / 0 LBS; Medic 2 85 KG / 187 LBS

BAGGAGE COMP.: Max 226 KG 40; Max 500 LBS 88

TAKE-OFF FUEL (LBS): 1600 (Max 1670)
LAND FUEL (LBS): 300 (Min 300)

	Weight	LMT	C OF G	AFT LMT
TAKE OFF	8987.0	119	251.0	129
LANDING	7687.0	119	248.9	129

PERFORMANCE PLANNING

PRES. ALT:	5500	FT
OAT:	25	°C
DENSITY ALTITUDE:	8004.25	FT
FUEL BURN:	AVE. 600 LBS PER HOUR	
CRUISE ALTITUDE:	6500	FT
OAT AT CRUISE ALTITUDE:	15	°C
CRUISE SPEED:	115	KNOTS
LEG FUEL BURN:	600	LBS
LONG RANGE CRUISE:		KIAS

TAKE OFF	Weight	Arm	Moment
Empty Weight (lbs):	6340.0	254.5	1613466.60
Flight Crew (lbs):	341	150.2	51218
Medic 3 & equip (lbs):	22	183.6	4039
Medic 1 (lbs):	187	186.9	34950
Stretcher (lbs):	0	223.5	0
FWD Facing Pax (lbs):	374	249	93126
Baggage Zone (lbs):	88	307.2	27034
Engine Oil (lbs):	35	308.2	10787
Total Fuel (lbs):	1600	263.3	421355
TOTALS:	8987.0	251.0	2255976
MAX:	9300		

LANDING	Weight	Arm	Moment
Empty Weight (lbs):	6340.0	254.49	1613467
Flight Crew (lbs):	341	150.2	51218
Medic 3 & equip (lbs):	22	183.6	4039
Medic 1 (lbs):	187	186.9	34950
Stretcher (lbs):	0	223.5	0
FWD Facing Pax (lbs):	374	249	93126
Baggage Zone (lbs):	88	307.2	27034
Engine Oil (lbs):	35	308.2	10787
Total Fuel (lbs):	300	261.5	78458
TOTALS:	7687.0	248.9	1913078

Chart 1: The ZT-RRT weight and balance. (Source: Operator)

Engine 1: (Left side)

Type	Rolls Royce 250-C40B
Serial Number	CAE-844249
Hours Since New	6013
Hours Since Overhaul	Modules

Engine 2: (Right side)

Type	Rolls Royce 250-C40B
Serial Number	CAE-844234
Hours Since New	4760.18
Hours Since Overhaul	Modules

1.6.7 The ZT-RRT helicopter was equipped with two (2) Rolls Royce 250 C4OB type turboshaft engines which were fitted since new to the helicopter at 0.0 airframe hours (A/F). The engines are designed with take-off power of 534 KW/715 SHP and are equipped with Chandler Evans' Full Authority Digital Control (FADEC) System.

1.6.8 According to information from AMO 1266, the number 1 engine, bearing (Serial Number) S/N CAE-844249 opening logbook dated 15 May 2020 indicated that the last modular overhaul was at 5719.6 engine hours and the helicopter had flown a further 294 hours. A 150-hour mandatory periodic inspection (MPI) was completed at 5872.5 hours on 24 September 2020 in accordance with (IAW) the maintenance manual.

1.6.9 The number 2 engine, bearing S/N CAE-844234 opening of logbook on 15 May 2020 indicated that in March 2013, the compressor was repaired, and further modular overhaul was completed at 4360.1 engine hours. The helicopter had flown a further 294 hours. A 150-hour MPI was completed at 4913.1 hours on 24 September 2020 IAW its maintenance manual.

Blue Main Rotor (M/R) Blade

Part Number	430-015-001-129
Serial Number	A-1959
Hours Since New	7234.5

NB: Originally, this MR was fitted to helicopter S/N 49109, then S/N49113, and finally S/N 49126 at 6450 airframe hours and the blade had 5997.4 hours. Snags reported on the blade included cracks found on the leading edge at 3784 hours and multiple blisters at 5997.4 hours. All the defects were fixed while the helicopter operated in east Africa.

Orange Main Rotor (M/R) Blade

Part Number	430-015-001-129
Serial Number	A-1903
Hours Since New	5135.5

NB: This MR was originally fitted to helicopter S/N 49108 as new and was removed at 673.8 A/F hours due to foreign object debris (FOD) damage. It was then fitted to the following S/Ns 49109 and 49102, respectively, before being fitted to S/N 49126 (accident aircraft). It was fitted on 10 July 2016 at 7244.1 A/F hours and the MR had accumulated 4841.5 hours.

Red Main Rotor Blade

Part Number	430-015-001-129
Serial Number	A-2188
Hours Since New	5012.8

NB: This MR was new and was fitted to the aircraft at 5070.6 airframe hours on 15 January 2012 by the AMO at Heli Malongo. At 4718.8 hours, the blade was sent for refurbishment before re-assembly in South Africa.

Green Main Rotor Blade

Part Number	430-015-001-129
Serial Number	A1773
Hours Since New	9359.1

NB: Originally, this MR was fitted to S/N 49102, then S/N 49109, and finally S/N 49126. The MR was repaired at 5501.7 hours before it was fitted to S/N 49109; another repair was done at 6139.3 hours on the trim tab that was debonded. The MR was fitted to S/N 49126 on 2 October 2015 at 6594 A/F hours and the blade had 8266.2 hours.

Blue M/R Pitch Link Assembly

Part Number	430-010-411-107	
Serial Number	US72	
Hrs since last Ins.	294	
Inspection	7730.5	15/05/2020
Total hours	8024.5	

Orange M/R Pitch Link Assembly

Part Number	430-010-411-107	
Serial Number	US 68	
Hrs since last Ins.	294	
Inspection	7730.5	15/05/2020
Total hours	8024.5	

Red M/R Pitch Link Assembly

Part Number	430-010-411-107	
Serial Number	US 69	
Hrs since last Ins.	294	
Inspection	7730.5	15/05/2020
Total hours	8024.5	

Green M/R Pitch Link Assembly

Part Number	430-010-411-107	
Serial Number	US 72	
Hrs since last Ins.	294	
Inspection	7730.5	15/05/2020
Total hours	8024.5	

Figure 3: Main rotor assembly.

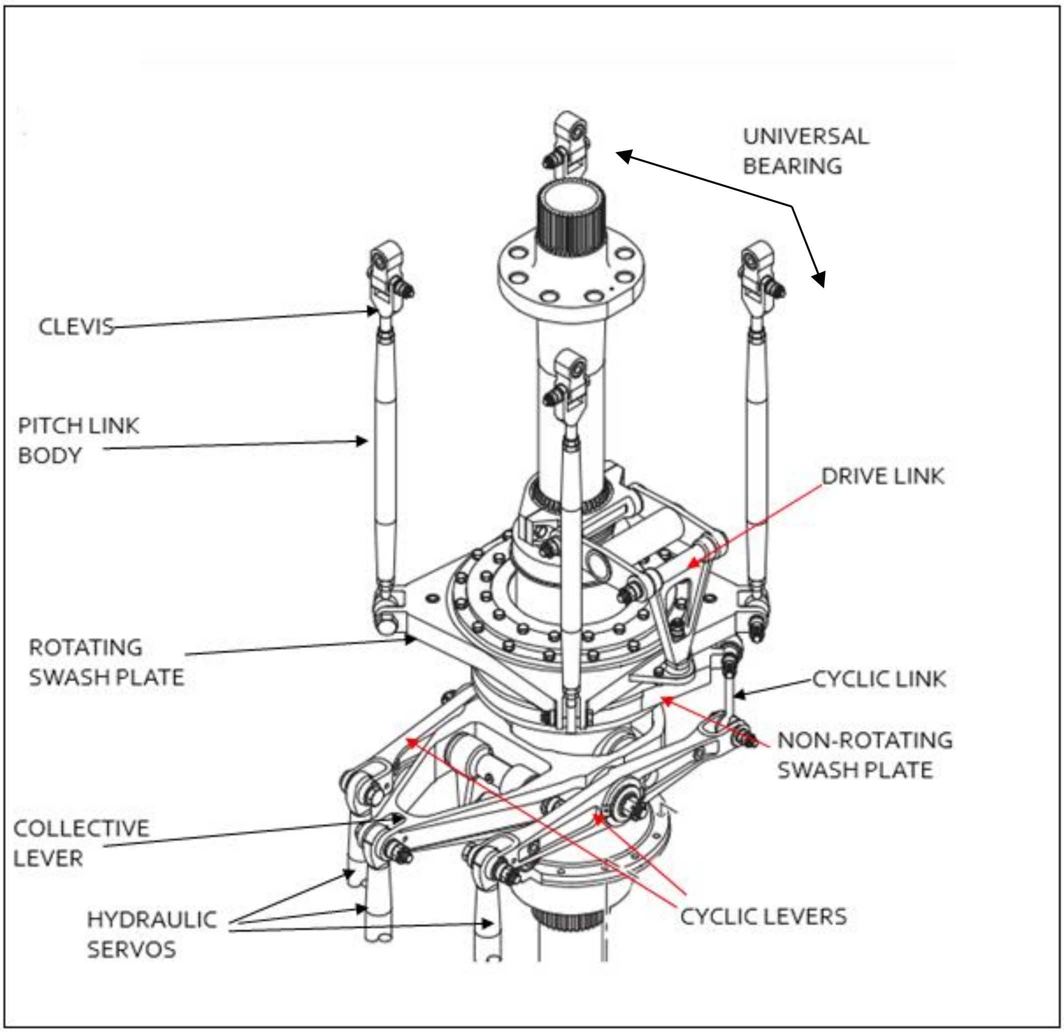


Diagram 1: Diagram showing main rotor mast assembly. (Source: Bell)

Hydraulic Servo Actuator: Left

Type	Woodwart
Part Number	222-382-001-111FM
Serial Number	HR673AB
Hours Since New	5728.7

NB: The servo was fitted as new to helicopter S/N 49126 but was later fitted to helicopter S/N 49102, and later, back to helicopter S/N 49126 on 4 January 2016. There were no further records found after that.

Hydraulic Servo Actuator: Middle (Pitch)**:**

Type	Woodwart
Part Number	222-382-001-111FM
Serial Number	HR671AB
Hours Since New	4917.0

NB: This servo was fitted new to helicopter S/N 49126 but was later fitted to helicopter S/Ns 49108, 49113 and 49102, and later back to helicopter S/N 49126 on 21 February 2015. There were no further records after that. This servo was responsible for pitching up and down movement of the collective and was, in turn, increasing or decreasing the angle of attack on the main rotor blades collective.

Hydraulic Servo Actuator: Right

Type	Woodwart
Part Number	222-382-001-111FM
Serial Number	HR619AB
Hours Since New	6939.5

NB: The servo was fitted new to helicopter S/N 49109 but was later fitted to helicopter S/N 49102, and, lastly, to helicopter S/N 49126 on 6 January 2016. There were no further records after that.

Tail Rotor (T/R) Blade 1:

Type	Composite
Serial Number	A-2031
Hours Since New	2912
Remainder (5000)	2087.1

NB: The TR was originally fitted to helicopter S/N 49102, 49108 and 49113, and was removed and reconditioned. It was then fitted to S/N 49126 on 27 March 2016 at 7057.5 A/F hours. The blade accumulated 2282.7 hours.

Tail Rotor (T/R) Blade 2:

Type	Composite
Serial Number	A-2288
Hours Since New	2202.5

NB: This T/R was first fitted to helicopter S/N 49002 at 4254.7 A/F hours, then to S/N 49040 and, lastly, to S/N 49126 on 14 April 2015 at 5917.6 A/F hours. The blade had accumulated 693.5 hours.

1.7. Meteorological Information

1.7.1 The weather report was supplied by the South African Weather Service (SAWS) on 28 January 2021, with Ladysmith as the closest reporting station, which is 12.45nm north-east of the accident site. The conditions were recorded between 1100Z and 1200Z.

Wind Direction	260°	Wind Speed	4kts	Visibility	9999m
Temperature	29°C	Cloud Cover	Nil	Cloud Base	Nil
Dew Point	18°C	QNH	1020hPa		

1.8. Aids to Navigation

1.8.1 The helicopter was equipped with standard navigational equipment as approved by the Regulator (SACAA) for the helicopter type. There were no recorded defects reported with the navigational equipment prior to the flight.

1.9 Communication

1.9.1 The helicopter was equipped with standard communication equipment as approved by the Regulator for this helicopter type. There were no recorded defects reported with the communication equipment prior to the flight. The helicopter was fitted with a Spidertracks device that is used by the operator to track movement of aircraft. The Spidertracks data was downloaded and the last tracked position is depicted in Figure 4.

1.10 **Aerodrome Information**

1.10.1 The accident did not happen at an aerodrome or within 10nm of a nearby aerodrome. The accident occurred 8nm north-east of Winterton, KwaZulu-Natal province, at GPS co-ordinates determined to be S28° 46’ 52.66” E029° 40’ 28.09” at an elevation of approximately 3301ft.

1.11 **Flight Recorders**

1.11.1 The helicopter was not fitted with a flight data recorder (FDR) or cockpit voice recorder (CVR), nor was it required by regulation to be fitted to the helicopter type.

1.12 **Wreckage and Impact Information**

1.12.1 The helicopter's last known position from the Spidertracks device is 361 (Figure 4). The helicopter was cruising at 725ft AGL parallel to the N3 Highway in a south-easterly direction, 146°. The eyewitness (the farmer) stated that he saw a red and white helicopter spinning around with objects being flung out of the helicopter. The helicopter maintained a south-easterly direction but started to lose height rapidly. Loss of control continued until the helicopter impacted the ground and burst into flames after flying over the main road which crosses overhead the N3 Highway. The Okhahlamba Fire Department declared the accident site safe after extinguishing the fire.

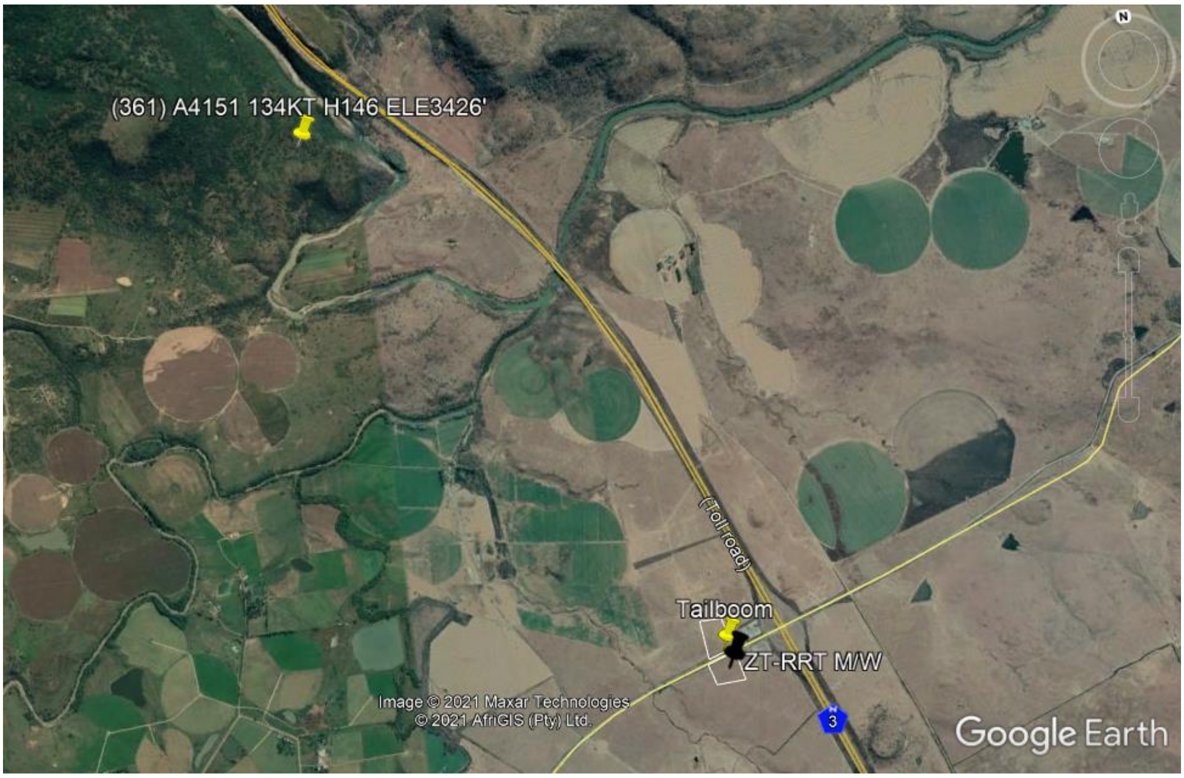


Figure 4: Point 361 is the last downloaded position of the helicopter. It is 2.4nm away from the main wreckage. (Source: Google Earth)

1.12.2 The objects that were flung out of the helicopter were some of its airframe parts that were severed by one or more of the helicopter's main rotor blades whilst spinning out of control, and some airframe parts that broke off because of the accident sequence. The accident site was divided into two sections; the first section was the tail boom site, and the second section was the main wreckage site. The accident site sections were separated by the main road leading to Winterton, south-west of the N3 Highway.

Figure 5: Schematic view of wreckage distribution. (Source: Google Earth)

1.12.3 **The Main Wreckage:**

The main wreckage was characterised by the remaining parts of the helicopter which were damaged by fire after impacting the ground. The cockpit and cabin section along with the entire airframe had fire damage. Components of the instrument panel were scattered around the main wreckage. The engine fire extinguishers were among the components lying next to the instrument panel. The engine compartment, with engines still attached, was one of the major components that were identifiable from the burned wreckage. The engine cowling and the nose cone were some of the airframe parts found furthest from the main wreckage. The engine driveshaft indicated that it failed due to overload. The left fuel tank and main transmission assembly with two of its main rotor blades separated from the airframe and did not have any sign of fire damage. The green main rotor blade broke off from the main rotor head and was located 148m from the main wreckage. There were 12 pressurised oxygen bottles on site and one of the bottles had some indication of fire damage which caused it to explode; however, 11 of the bottles were accounted for. Debris from the damaged main rotor blade(s), pieces of Perspex from the helicopter windows and windshield (still attached to the overhead circuit breaker panel) were found north of the main wreckage.

Figure 6: Main wreckage post-accident.

Figure 7: The main transmission assembly.

Figure 8: Green main rotor blade.

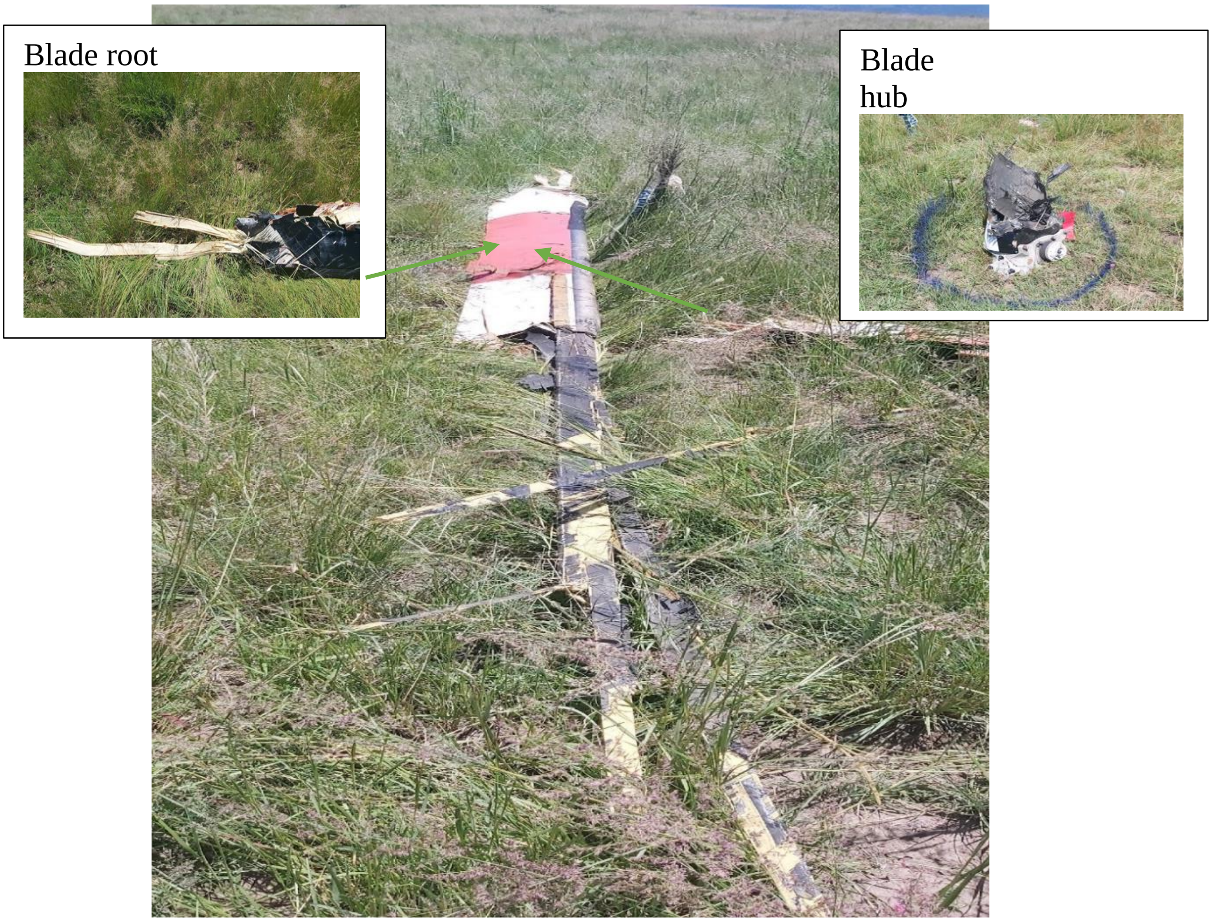


Figure 9: Orange main rotor blade located 94m from the tail boom.

1.12.4 **The Tail Boom Site:**

The tail boom, right horizontal stabiliser and vertical stabiliser were found north of the road, approximately 90m from the main wreckage. The damage observed to the tail boom was indicative of a main rotor blade contact on the left side and on the top side as indicated by the blade profile indentation mark on the tail rotor shaft cover. The tail driveshaft middle shaft was still attached to the tail boom. The driveshaft was observed to have rotational marks (in the direction of rotation) indicative of normal operation before impact. The left horizontal stabiliser had separated from the tail boom and was found 100m from the tail boom. Damages observed on the left horizontal stabiliser were indicative of an object which was severed by contact with the main rotor blade as the top-half of the vertical fin was missing. Two main rotor pitch link controls (one marked orange and the other blue) were also found closer to the tail boom. The tail rotor assembly was missing one blade, which had broken off from the tail boom and landed 79.3m from the main wreckage after separating from the tail boom. Damaged observed on the tail gearbox was as result of sudden stoppage. There was continuity observed on the 90˚ output shaft.

1.12.5 In Figure 7, the two blades marked Red and Blue were still attached to the upper yoke and rotor hub. The two upper stops aligned with them were broken off during the accident sequence. The other two blades marked Green and Orange and their attaching lower yokes broke off and landed at two different locations. The two remaining upper stops on the main hub correspond to their (Green and Orange) positions before the accident. The Orange blade (Figure 9) caused more damage than any of the other three blades. The damage on the blade towards the end confirms that this blade is responsible for most of the damage that was sustained by the helicopter. Figure 9 (left inset) shows the root of the blade which is not clear when it separated from the M/R and Figure 9 (right inset) shows part of the yoke was still attached to the M/R blade. The complete thickness of the blade only runs up to two-thirds of its length and the last one-third is destroyed and only the front spar is still attached. The Green blade broke away from the helicopter with some of the yoke but remained intact and did not inflict any damage to the helicopter.

Figure 10: The tail cone assembly repositioned upright was located 129.9m from the main wreckage. (Inset): Left horizontal stabiliser.

1.13 **Medical and Pathological Information**

1.13.1 The post-mortem and blood toxicology reports were still outstanding at the time of compiling this report. Should any of the results have a bearing on the circumstances leading to this accident, it will be treated as new evidence that will necessitate the reopening of this investigation.

1.14 Fire

1.14.1 Soon after the helicopter impacted the ground, it burst into flames and most of the helicopter's airframe parts were destroyed. The gearbox with two main rotor blades (blue and red in Figure

7) still attached as well as the left-side fuel tank had broken off from the aircraft and were not burnt. Local fire services were called to extinguish the fire and they also assisted in locating most of the helicopter parts by marking them with visible flags.

1.15 Survival Aspects

1.15.1 The accident was considered not survivable due to the damage caused to the cockpit and cabin, which resulted in fatal injuries to all occupants on-board.

1.16 Tests and Research

A. The Rolls Royce Engine Investigation Report:

1.16.1 The engine report of the two engines inspected at the AMO engine facility, South Africa (SA), on 28 January 2021 had the following results (Annexure K):

- *The logbooks were reviewed and were found to be in order.*

Figure 11: (Engine No.1) gearbox and turbine. **Figure 12:** (Engine No.1) compressor.

- *The gearbox of engine No1 was consumed by the post-crash fire and two gears were recovered - the Torque meter gear assembly and an idler gear. Neither gear displayed missing teeth or other pre-impact anomalies. The fuel system hydromechanical unit (HMU), which is normally mounted on the gearbox, was not recovered. The engine electronic control unit (ECU) suffered extreme thermal damage, so it was not interrogated.*

- *Several of the compressor impeller blades displayed mechanical damage to include bending opposite the direction of normal rotation. The outboard portions of the blades and aft side of the impeller were discoloured and scored consistent with contact between the rotor and surround stationary hardware while rotating. Corresponding rub indications were observed on the compressor rear support and shroud.*

Figure 13: (Engine No.2) As it was recovered.

- *A field data download of the engine No.2 ECU was executed during the engine examination. The ECU includes an incident recorder function, which begins capturing engine and input parameters upon trigger actuation and records a line of data ("record") every 1.2 seconds. The incident recorder, although functional, did not retain data in this event likely due to a sudden electrical power interruption as the aircraft broke up in flight. The ECU system also retains routine maintenance information throughout the life of the engine which is retained in the maintenance terminal section. The maintenance terminal data from engine No.2 indicated that there were no pre-event abnormalities which would have affected engine operation during the event. In the twin engine installation, the ECU also captures data when one engine is inoperative (OEI). As the engine No2 ECU data did not reflect any OEI events, it can be inferred that the engine No1 was operating normally prior to the event as well.*

- *No abnormalities were observed during the engine exam which would affect engine operation during the accident flight. The damage noted to both power turbine sections was consistent with a loss of load during the impact sequence and subsequent overspeed of the power turbine rotors. Multiple rotational and operational signatures were observed in both engines which confirm engine operation during the accident sequence.*

- *Power is supplied to the transmission through the two main drive shafts. Each shaft has a flexible splined coupling at both ends which provides link between the engine and the transmission.*

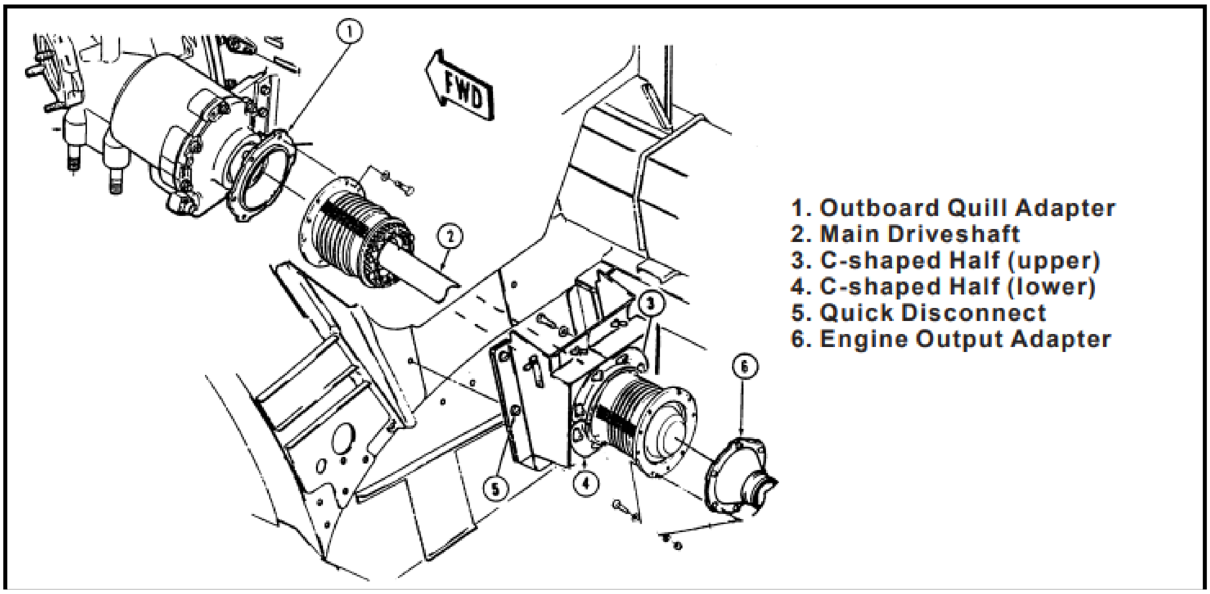


Diagram 2: Drive shaft connection between the engine and the transmission.

- *Both driveshafts got separated from the engine and transmission, and on examination they were found in good condition. On both ends of the two driveshafts, the inner spherical gears and outer gears were lined up perfectly, indicating no damage at all.*

Figure 14: Engine No1 drive shaft

Figure 15: Engine No2 Drive shaft

- *The transmission which is mounted forward of the powerplant is driven by the respective driveshafts from the two engines to supply different RPM to the main and tail rotors. Each driveshaft is connected to the transmission gearbox through the power input quill. The quill incorporates a sprag-type freewheeling clutch which permits single engine operation. During post-examination, it was found that the two drive quills were freewheeling and that there was continuation from the drive quill to the main rotor outputs.*

B. The Hydraulic servos. The hydraulic servos were tested by qualified technicians at the operator's AMO, and the investigating team was present during testing.

Figure 16: Tail rotor servo.

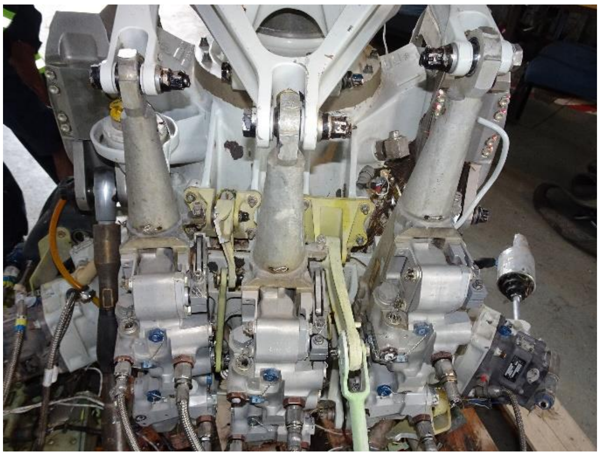


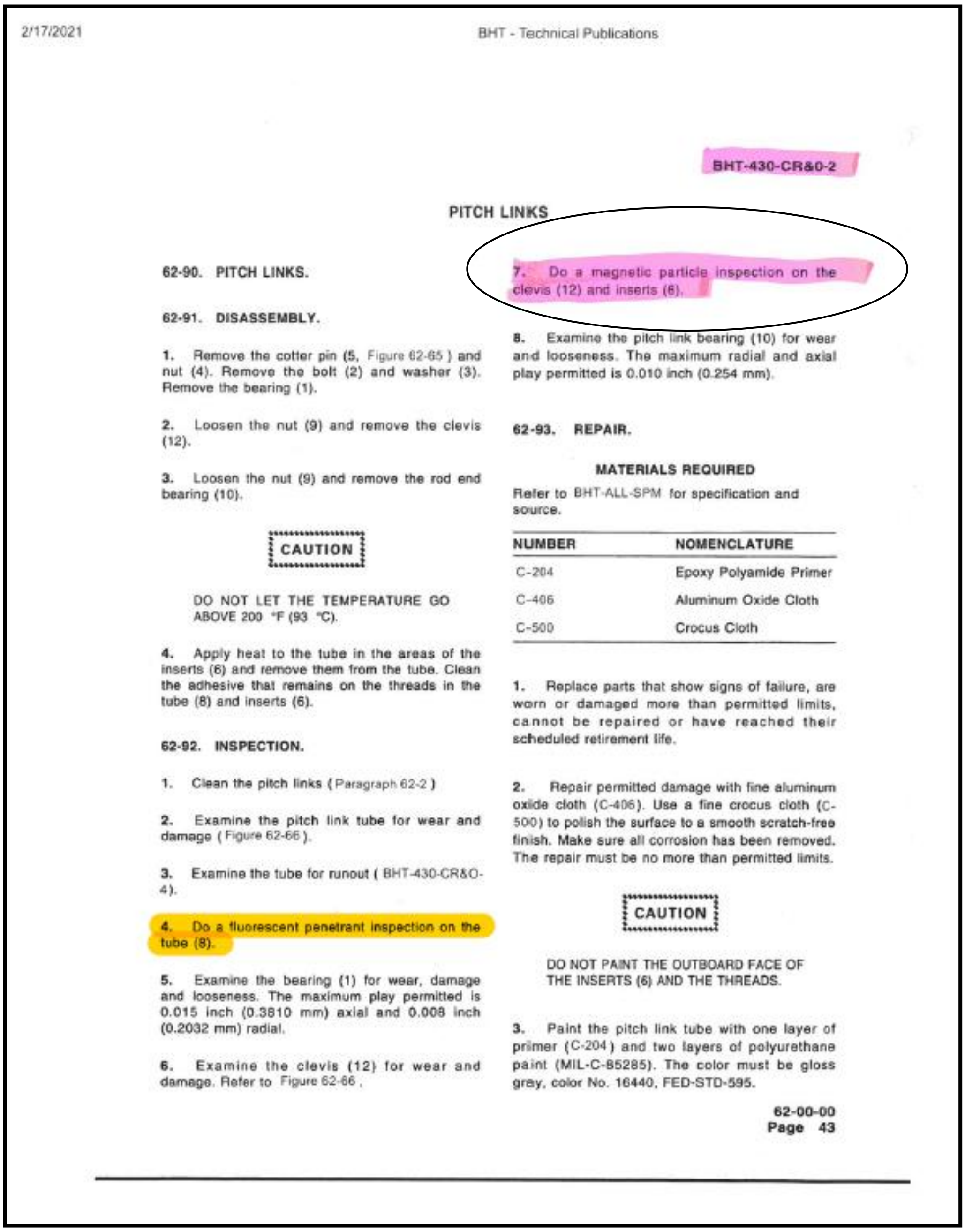
Figure 17: Three main rotor servos.

- *The tail rotor servo was completely burnt and could not be tested. The three dual hydraulic servos attached to the transmission that were removed from the transmission assembly were attached to a hydraulic rig to test their functionality. The left-side servo S/N HR673AB and right-side servo S/N HR619AB were tested on both systems and the piston extended and retracted to its full length of 6 inches. The middle servo S/N HR671AB could only be tested on one system because the other system had accident damage on the return line. The tested system also extended and retracted the piston to its full length.*

C. **Pitch Control Links, Main Rotor Control Assembly** by the University of Pretoria (UOP), Laboratory for Microscopy & Microanalysis (Annexure I):

Figure 18: Components sent for analysis.

1.16.2 During post-investigation at the AMO hangars at Rand Airport, it was determined that some components associated with the control of the main rotor assembly required extensive tests as they had failed before their respective scheduled removal hours as per the Bell historical service record manual Model 430. According to the Bell model 430 helicopter component replacement, all main rotor link assembly components (See Figure 18 (1) tube assembly, (2) rod end, (3) clevis and (4) universal bearing) had a life of 10 000 hours. Of all the M/R link assembly components that got replaced, the universal bearing was frequently changed. Hence, research of the failed components and the causes, thereof, was assigned to Laboratory for Microscopy and Microanalysis of the University of Pretoria. The second issue of the final report was released on 28 April 2021. The full report is attached as Annexure G.



2/17/2021 BHT - Technical Publications

BHT-430-CR&O-2

PITCH LINKS

62-90. PITCH LINKS.

62-91. DISASSEMBLY.

1. Remove the cotter pin (5, Figure 62-65) and nut (4). Remove the bolt (2) and washer (3). Remove the bearing (1).

2. Loosen the nut (9) and remove the clevis (12).

3. Loosen the nut (9) and remove the rod end bearing (10).

CAUTION

DO NOT LET THE TEMPERATURE GO ABOVE 200 °F (93 °C).

4. Apply heat to the tube in the areas of the inserts (6) and remove them from the tube. Clean the adhesive that remains on the threads in the tube (8) and inserts (6).

62-92. INSPECTION.

1. Clean the pitch links (Paragraph 62-2)

2. Examine the pitch link tube for wear and damage (Figure 62-66).

3. Examine the tube for runout (BHT-430-CR&O-4).

4. Do a fluorescent penetrant inspection on the tube (8).

5. Examine the bearing (1) for wear, damage and looseness. The maximum play permitted is 0.015 inch (0.3810 mm) axial and 0.008 inch (0.2032 mm) radial.

6. Examine the clevis (12) for wear and damage. Refer to Figure 62-66 .

7. Do a magnetic particle inspection on the clevis (12) and inserts (6).

8. Examine the pitch link bearing (10) for wear and looseness. The maximum radial and axial play permitted is 0.010 inch (0.254 mm).

62-93. REPAIR.

MATERIALS REQUIRED

Refer to BHT-ALL-SPM for specification and source.

NUMBER	NOMENCLATURE
C-204	Epoxy Polyamide Primer
C-406	Aluminum Oxide Cloth
C-500	Crocus Cloth

1. Replace parts that show signs of failure, are worn or damaged more than permitted limits, cannot be repaired or have reached their scheduled retirement life.

2. Repair permitted damage with fine aluminum oxide cloth (C-406). Use a fine crocus cloth (C-500) to polish the surface to a smooth scratch-free finish. Make sure all corrosion has been removed. The repair must be no more than permitted limits.

CAUTION

DO NOT PAINT THE OUTBOARD FACE OF THE INSERTS (6) AND THE THREADS.

3. Paint the pitch link tube with one layer of primer (C-204) and two layers of polyurethane paint (MIL-C-85285). The color must be gloss gray, color No. 16440, FED-STD-595.

62-00-00
Page 43

Figure 19: Bell 430 technical publication instructs that the clevis should be subjected to MPI testing.

COMPILED FOR: SACAA (AIID)	**FAILURE ANALYSIS REPORT: MAIN ROTOR PITCH CONTROL LINK ASSEMBLY, BELL 430, REGISTRATION No ZT-RRT**	**DOCUMENT NUMBER** FA-006-03-21	
		DATE 2021-04-28	**ISSUE** FINAL

6.5. Magnetic Particle Inspection (MPI), Permeability, ASTM1444 and Threaded parts:

Magnetic Particle Testing consists of magnetizing the area to be examined, applying suitably prepared magnetic particles while the area is magnetized, and subsequently interpreting and evaluating any resulting particle accumulations. Maximum detectability occurs when the discontinuity is positioned on the surface and perpendicular to the magnetic flux.

Permeability is the measure of magnetization that a material obtains in response to an applied magnetic field. In general, permeability is not a constant, as it can vary with the position in the medium, the frequency of the applied magnetic field, humidity, temperature, and other parameters. In a nonlinear medium, the permeability can depend on the strength of the magnetic field. In ferromagnetic materials this depends on the history of the material (residual magnetism from previous NDT testing, lightning strikes, etc.) The permeability of 15-5 PH in the hardened condition conforms to a Moderately Magnetic classification. ASTM1444 Appendix X1 notes that care should be taken with low permeability steels, i.e. 15-5 PH, to ensure a high enough amperage to ensure a strong magnetic field strength.

MPI on **Threaded Parts** may hold some challenges towards correct interpretation as the thread roots might render *false* indications by design (Figure 2, red arrows) or indications may even be discounted. In contrast, used plated parts may render no indication if the plating material *smeared* over a surface fracture during removal/fitment. This should be completed by a qualified (Level) and experienced NDT Inspector.

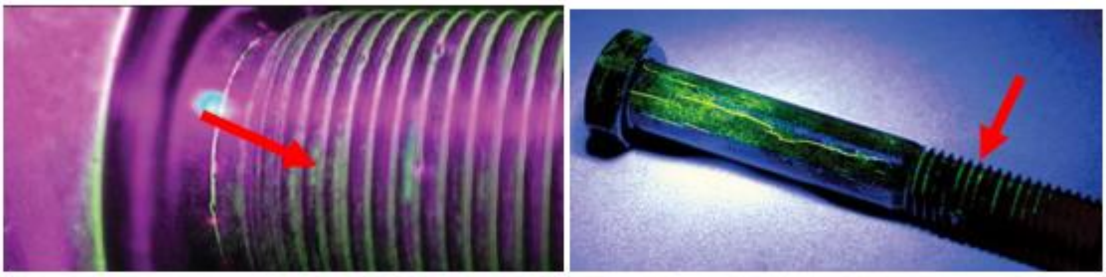


Figure 20: Taken from the University of Pretoria report.

1.16.3 Figure 20 is taken from the University of Pretoria report:

Fatigue Fracture Initiation and Progression Rate

Fatigue fracture initiation requires a minimum crack size (a) that would result in a surface stress concentration which in turn will initiate the fatigue fracture progression. Pitting corrosion and/or damage exceeding the minimum surface crack size (a) proved to be a common cause towards the fatigue of metals.

Pitting corrosion *https://www.nace.org/resources/general-resources/corrosion-basics/group-3/stress-corrosion-cracking*

Pitting corrosion is a localised form of corrosion by which cavities or "holes" are produced in the material. Pitting is more dangerous than uniform corrosion damage because it is more difficult to detect, predict. A small, narrow pit with minimal overall metal loss can lead to the failure of an entire engineering system.

Pitting is initiated by: *https://www.nace.org/resources/general-resources/corrosion-basics/group-3/stress-corrosion-cracking*
Localised chemical or mechanical damage to the protective oxide film; water chemistry factors which can cause breakdown of a passive film are acidity, low dissolved oxygen concentrations (which tend to render a protective oxide film less stable) and high concentrations of chloride (as in sea water).

Stress corrosion cracking (SCC) is the cracking induced from the combined influence of tensile stress and a corrosive environment. The impact of SCC on a material usually falls between dry cracking and the fatigue threshold of that material. The required tensile stresses may be in the form of directly applied stresses or in the form of residual stresses, see an example of SCC of an aircraft component. The problem itself can be quite complex. The situation with buried pipelines is a good example of such complexity.

Stress Corrosion Cracking (SCC)
Stress Corrosion Cracking (SCC) refers to cracking caused by the simultaneous presence of a tensile stress and a specific corrosive medium. Operational loads on the PCL clevis constitutes an applied and variable tensile stress and the historic operational environment of the accident aircraft involved a corrosive medium. 15-5 PH proved to be highly susceptible to SCC in a seawater environment.

Hydrogen Embrittlement (HE)
Hydrogen Embrittlement sort under the ''Hydrogen Damage'' type of corrosion. The mechanism involves the penetration of atomic Hydrogen (H+) into the metal matrix when a disparity in concentration of H+ is present between the metal surface and the matrix. This concentration gradient is most prevalent during the metal surface plating processes.

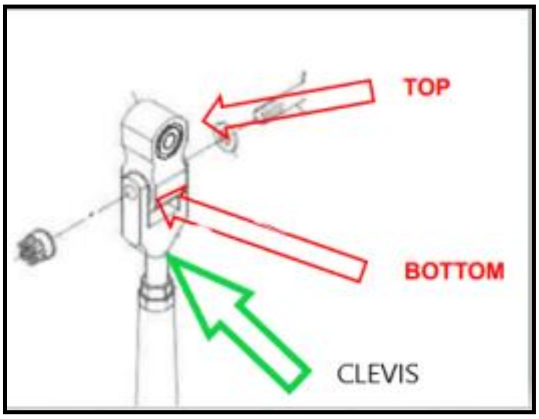


Diagram 3: Universal bearing assembly.

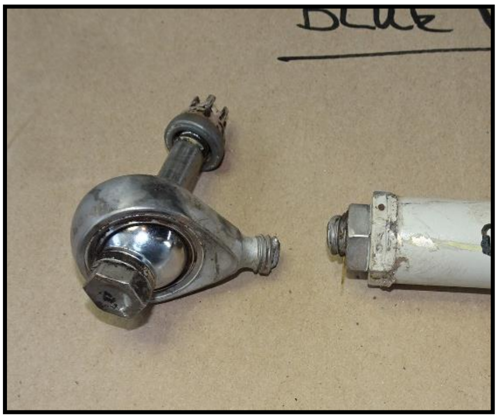


Figure 21: Bottom rod end/bearing.

Torque Tests on the Universal Bearing

A qualitative torque test was performed on selected units to compare the noted resistance to rotational movement of the Universal Bearings, top and bottom as indicated (Diagram 3). This was not a standardised test but used for comparative analysis only. Notably the bottom bearing from the ORANGE PCL Universal Bearing assembly revealed the highest resistance at 0.38442 Nm and its top bearing was 0.0574 Nm.

The fracture morphology generally depicts both inter- and trans-granular features in high strength materials depending on the microstructure and/or the environment. Cracking proceeds generally perpendicular to the applied tensile stress with some extent of ''branching'' at the crack tip. The criteria for stresses are simply that they need to be tensile and of sufficient magnitude. The time to failure is depending on the applied stress and the remaining cross-sectional area of the specimen. However, in the normal PCL Clevis operating environment, the applied tensile stress will in addition have a variable component resulting in the initiation of a fatigue failure mode till final failure rather than a pure SCC mode.
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The time to failure is depending on the applied stress and the remaining cross-sectional area of the specimen. However, in the normal PCL Clevis operating environment, the applied tensile stress will in addition have a variable component resulting in the initiation of a fatigue failure mode till final failure rather than a pure SCC mode.

There is still no clear consensus towards the exact differentiation between HE and SCC. In the case of Hydrogen absorption from manufacturing, intentional or not, resulting in a fracture at lower-than-normal stresses, it is classified as HE. In the case where hydrogen is absorbed due to the corrosion reaction it is classified as SCC. However, the possible transition between, or combination of, corrosion types during the initial phase of the fracture render the isolation of the predominant phenomena challenging.

Notwithstanding, in the operating environment of the MR PCL Clevis under investigation, the initiation of a fatigue fracture due to the corrosion induced damages proved to be the predominant causational factor.

Figure 22: Orange and Red PCL.

Scheduled Maintenance Inspections

The OEM supplied information depicting the total Airworthiness Life of the Main Rotor Pitch Link Assembly, part no 430-010-411-105/-107, as 10 000hr. The remaining life at the time of failure relating to the ORANGE MR PCL clevis was ~1975.5hr.

Scheduled inspections involve the inspection of the pitch link tube for wear, damage and runout and perform FPI; bottom end bearing for wear, damage, looseness, axial- and radial play limits; upper clevis for wear and damage and perform MPI; universal bearing for wear, looseness, radial- and axial play limits.

Notably, no resistance to rotation inspection is prescribed for the 2x bearings forming part of the upper universal bearing assembly. To complete such an inspection, the universal bearings will have to be removed and isolated from the assembly. While the removal of the two bolts are prescribed for the 2X Calendar Year Inspection (Extract 1 (b)), no reference towards inspecting for resistance to rotation is mentioned. Furthermore, detecting the (maximum) allowed 0.254mm axial/radial play (Extract 1 (c)) by mere feel and without calibrated instrumentation while the universal bearing is still attached (as per 50- and 300-hour inspections), could be considered challenging.

According to the historic information, the last NDT on the set MR PCL Clevises (4x) originating from the accident aircraft was completed on the 24th of January 2020 by an approved NDT entity to ASTM 1444M-16e1 (Extract 1 (a)). No recordable defects were found. This test was not scheduled but included as an over-and-above requirement by the AMO at the time of the registration process of the accident aircraft in South Africa (ex-Angola). No further indications of similar inspections during the ~296h operational hours since were noted from the supplied information.

Figure 23: Clevises from the blue and green PCL.

Clevises:

The ORANGE and RED Clevises revealed fractures within the protruding threaded sections (Figure 22). The remaining BLUE and GREEN units revealed bending and impact damages only (Figure 23). The visual inspection of the ORANGE Clevis fracture surface revealed indications of a fatigue failure mode (Figure 24) suggesting it to be the primary failure initiating the accident sequence of events. The variation in impact damages between the ORANGE and the remainder of the M/R PCL Tubes (Figure 18) support this hypothesis. The RED Clevis as well as all the bottom PCL ends/bearings fractures and damages can be attributed to impact forces.

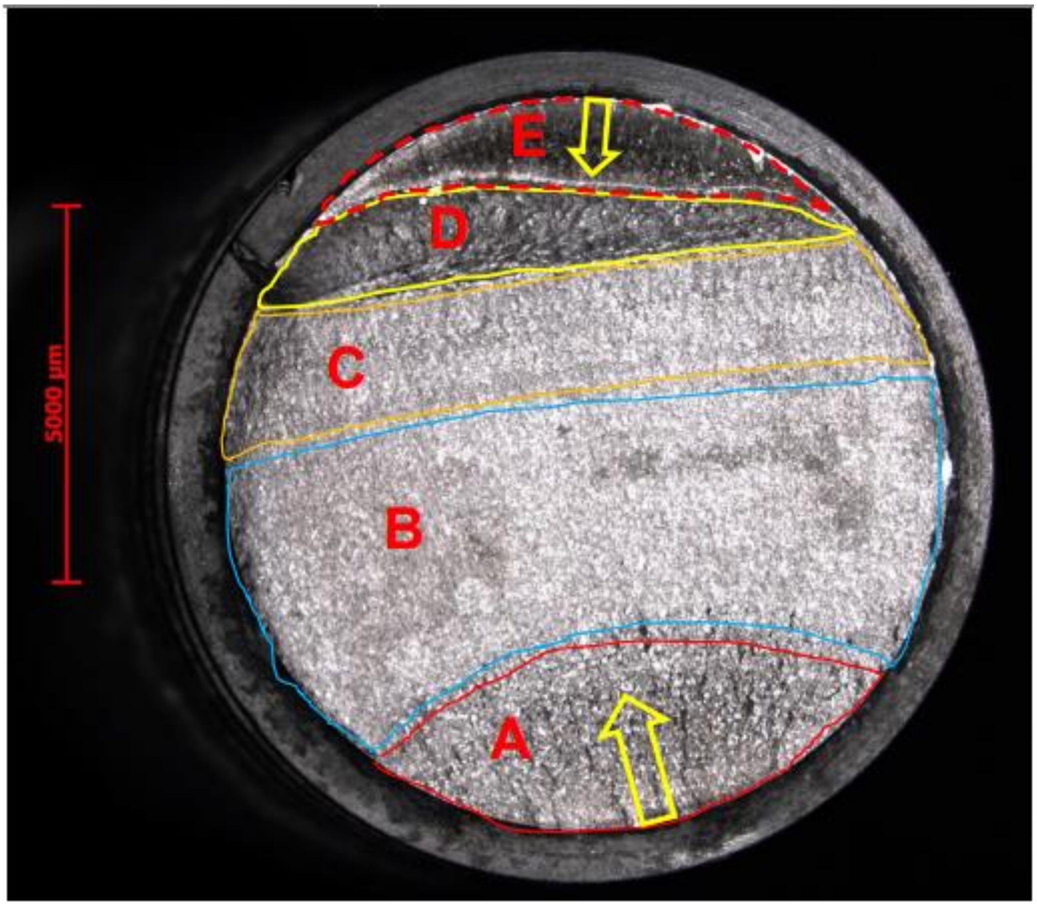

Figure 24: The Stereo-microscope inspection revealed a fracture surface geometry with distinct zones. The fatigue fracture initiated at opposing positions at the thread root and within Zones A and E, suggesting an alternating and opposing but unequal applied bending stress during operation.

Zone D depicts the fast (final) fracture position. The fatigue fractures progressed towards Zone D as indicated (Yellow arrows). Zone A represents the initial fracture start area, Zone B a stable fracture progression rate with Zone C indicating an increased progression rate due to the increasing nominal stress (applied stress/remaining thickness). The break-up of the protective cadmium (Cd) coating, acting both as a barrier to environmental exposure and as cathodic protection, will be detrimental to the corrosion resistance properties of the base alloy. The fracture surface morphology at the initiation area, Zone A, revealed extensive inter-granular attack with intermitted trans-granular. Both these morphological features are consistent with HE and/or SCC corrosion attack. Extensive post-fracture initiation pitting corrosion was evident (Yellow circles, in report) suggesting exposure to a corrosive environment for an extended period. Once the minimum flaw/crack size were reached at the end of Zone A, a fatigue fracture morphology became predominant in Zones B and C with the striation geometry suggesting a high cycle/low stress exposure with a clear progression direction (Yellow arrows). Zone D corresponds with fast, final fracture displaying the typical micro-void coalescence dimple morphology. Zone D represents approximately 15% of the total fracture surface area. Zone E displayed similar features to the Zone A's fracture initiation area with clear inter- and trans-granular features. The secondary corrosion attack (Yellow *dashed circles) is more severe than Zone A suggesting that either the fracture progression was arrested for a period following initiation while exposed to the environment, or the clevis was rotated (180°) during maintenance thus relocating the applied stress concentration to Zone A. The remainder of Zone E displays a fatigue fracture mode up to Zone D. Thread roots adjacent to the fracture initiation revealed clear indications of secondary fractures and surface plating break-up.*

Conclusion

The disparity in damages between the ORANGE and the remaining (RED/BLUE/GREEN) units support the hypothesis that the ORANGE Clevis failed during operation, initiating the accident sequence of events. The damages and fractures relating to the tubes, bottom tube-ends and bearings can be attributed to impact forces.

The comparative torque test results obtained shows the bottom bearing from the ORANGE Universal Bearing assembly (TTSN ~1705.5h) to have the highest resistance to rotation with a clear ''ratchet'' effect during rotation. "The "ratchet" effect can be attributed to the preferential positioning (stationary relative to outer raceway) of the bearing rollers during operation resulting in extensive localised wear. This noted resistance to rotation will affect the applied mean (average) stress profile on the clevis during operation. The noted ''binding'' at the ORANGE Pitch Horn inserts/top bearing interfaces can be a resultant effect of this resistance to rotation.

ORANGE Clevis: The fracture initiated within thread root between the shank and the lock-nut position. The fracture surface revealed clear inter- and trans-granular features at the two opposing initiation areas suggesting corrosion attack to be the primary contributing factor. On reaching the critical flaw size, the fracture progressed in fatigue failure mode up to final (fast) fracture. The fatigue fracture progression geometry conforms to a high cycle/low stress regime and with final fracture surface representing ~15% of the total area.

1.17 Organisational and Management Information

1.17.1 The flight was conducted under visual flight rules (VFR) and under Part 138 of the Civil Aviation Regulations (CAR) 2011 as amended. The helicopter was duly authorised to operate under the Air Operating Certificate (AOC).

1.17.2 The operator was in possession of a valid AOC CAA140D under Part 127 with endorsement of Part 138 by the Regulator, which was issued on 1 September 2020 with an expiry date of 31 May 2021 (Annexure H).

1.17.3 The AMO which carried out the last maintenance inspection on this helicopter was issued an AMO approval on 7 September 2020 with an expiry date of 31 May 2021. The helicopter type was duly authorised to be maintain under the AMO.

1.17.4 The helicopter was modified and fitted with Emergency Medical Services (EMS) equipment in accordance with Air Methods Corporation STC: SR00514DE-D. Another modification was the Articulate Patient Loading System (APLS) with STC: SR00235DE-D.

1.17.5 The helicopter was maintained by certified AMO and was released to service on 23 September 2020 after completing a 150-hour MPI at 7546.6 airframe hours. The helicopter had flown a further 141.1 hours before the accident. The next MPI was due on 23 September 2021 or at 7693.7 airframe hours, whichever occurs first.

1.17.6 The same AMO had carried out a 150-hour mandatory periodic inspection (MPI) on the helicopter, with the next MPI due on 23 September 2021 or at 7693.7 hours, whichever occurs first.

1.17.7 The manufacturer, Bell Engineering Laboratories' Report 43017M-015EXT Export Class C ECCN 9E991, written on 14 August 2017 detailing the cause of the accident, found that the upper pitch link clevis for the Orange main rotor blade fractured due to fatigue. This fracture would have resulted in the Orange blade losing pitch control. The manufacturer did not issue any safety recommendations at the time.

1.18 Additional Information

Source: Rotorcraft Flying Handbook FAA-H-8083-21, Chapter 3

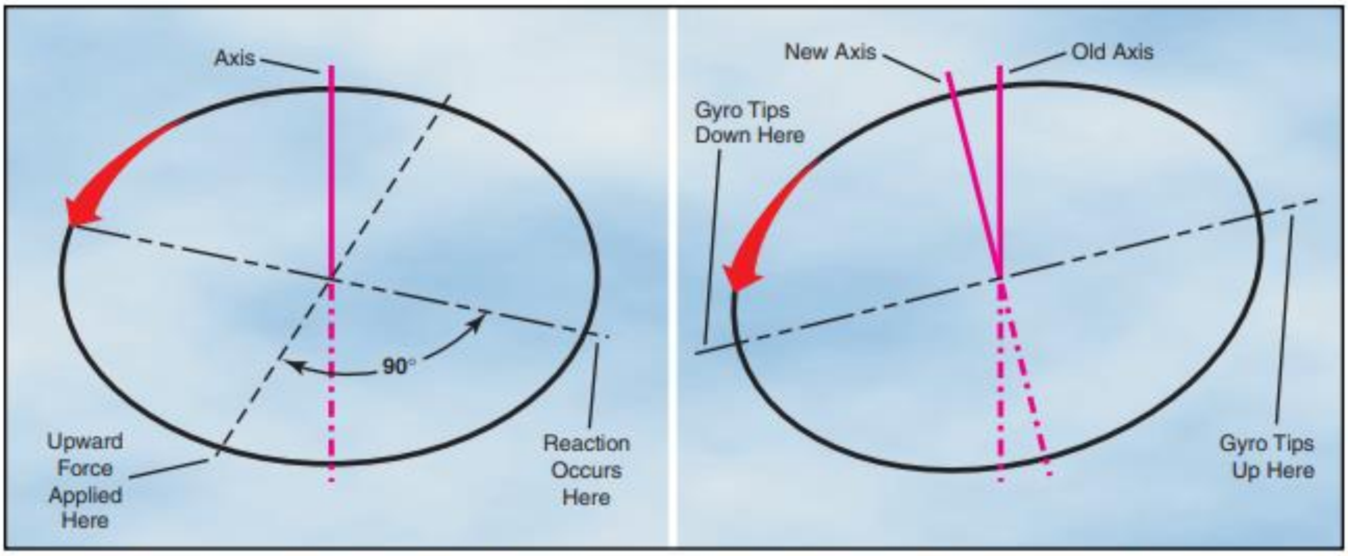

Figure 3-8. Gyroscopic precession principle—when a force is applied to a spinning gyro, the maximum reaction occurs approximately 90° later in the direction of rotation.

Illustration 1: Gyroscopic precision principle.

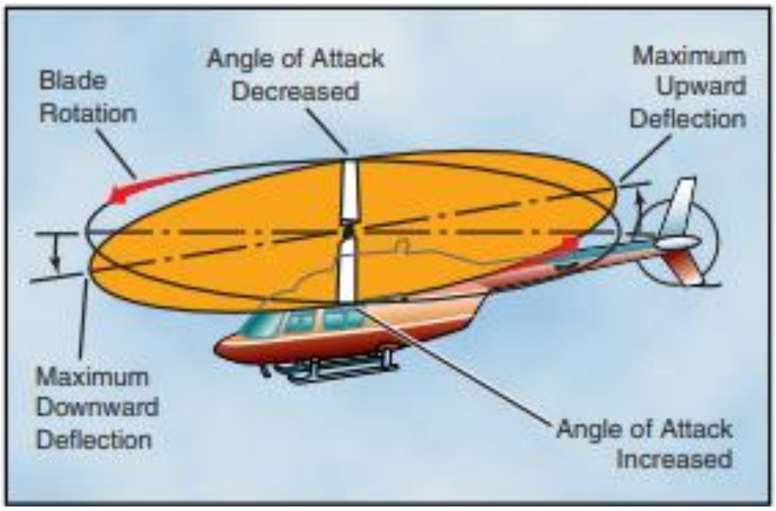

Figure 3-9 With a counter-clockwise main rotor blade rotation, as each blade passes the 90° position on the left, the maximum increase in angle of attack occurs. As each blade passes the 90° position to the right, the maximum decrease in angle of attack occurs. Maximum deflection takes place 90° later—maximum upward deflection at the rear and maximum downward deflection at the front—and the tip-path plane tips forward.

Illustration 2: Upward and downward deflection of blades.

GYROSCOPIC PRECESSION

1.18.1 The spinning main rotor of a helicopter acts like a gyroscope. As such, it has the properties of gyroscopic action, one of which is precession. Gyroscopic precession is the resultant action or deflection of a spinning object when a force is applied to this object. This action occurs approximately 90° in the direction of rotation from the point where the force is applied.

(Illustration 1) Let us look at a two-bladed rotor system to see how gyroscopic precession affects the movement of the tip path plane. Moving the cyclic pitch control increases the angle of attack of one rotor blade with the result that a greater lifting force is applied at that point in the plane of rotation. This same control movement simultaneously decreases the angle of attack of the other blade the same amount, thus decreasing the lifting force applied at that point in the plane of rotation. The blade with the increased angle of attack tends to flap up; the blade with the decreased angle of attack tends to flap down. Because the rotor disk acts like a gyro, the blades reach maximum deflection at a point approximately 90° later in the plane of rotation. As shown in Illustration 2, the retreating blade angle of attack is increased and the advancing blade angle of attack is decreased resulting in a tipping forward of the tip-path plane, since maximum deflection takes place 90° later when the blades are at the rear and front, respectively in a rotor system using three or more blades, the movement of the cyclic pitch control changes the angle of attack of each blade an appropriate amount so that the end result is the same.

History of Four (4) Bell 430 Helicopters (Heli Malongo)

1.18.2 The accident helicopter was one of four helicopters operated by Heli Malongo, an Angolan owner/operator in 2006. The helicopters operated non-scheduled commercial flights, transporting Chevron employees between Heli Malongo heliport and Tombua-Landana off-shore (an oil platform 38nm into the Pacific Ocean). On 26 September 2016, one of the helicopters, D2-EYI, crashed in the Pacific Ocean at the Tombua oil fields. The helicopter had a total of 10079:00 airframe hours and 41420 cycles. It took 25 days to search and recover 95% of the debris; six of the occupants were fatally injured. Gabinete de Prevenção e Investigação de Acidentes com Aeronaves (GPIAA) (English: Office for the Prevention and Investigation of Accidents in Civil Aviation and Rail) final report for Bell 430 with registration D2-EYI, operated by Heli Malongo dated 28 August 2018, was released; the report established that '*the probable cause of the accident was the break off of the main rotor pitch link clevis from the orange blade".* A Bell Engineering Laboratories Report 43017M-015EXT Export Class C ECCN 9E991 written on 14 August 2017 attached as Appendix B, found the following:

Blades and Yokes:
The four blades and yokes were received as shown in Figure 25. All fractures observed on the blades and yokes were consistent with overload. There was no rubbing damage, indicative of a delamination prior to fracture, observed between the plies of the composite yokes.
Orange: *The abrasion strip was missing from the outer third of the Orange blade's span and the spar had broken from impact damage. The wiring tangled in the fractured spar material*

was reportedly traced to wiring found only in the cabin. The extent of the damage to the blade and the presence of the wiring suggested the Orange blade was the first to strike the cabin.

Red: *The Red blade followed the Orange in rotation and had impact damage to its leading edge in a similar location (span-wise), but to a lesser extent.*

Green: *The Green blade fractured from the portion attached to the leading-edge blade adapter bolt. The blade remained attached to the yoke and adapter at the aft adapter bolt.*

Blue: *The Blue blade fractured in the cuff portion between the adapter and the blade attachment bolts. The aft tip weight package was missing. It could not be determined if the tip weights were lost during the accident sequence or as part of the recovery process.*

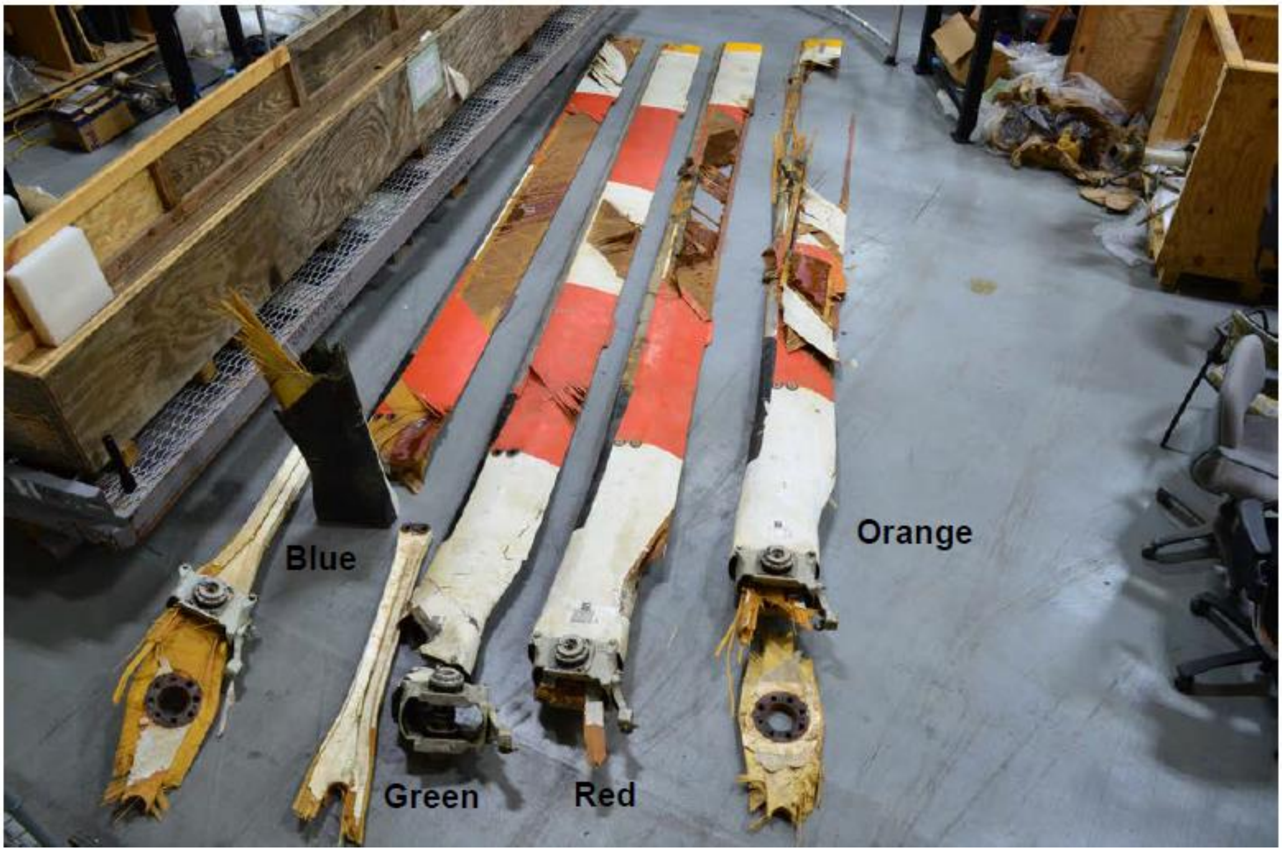

Figure 25: The damages sustained by the blades of a Bell 430, registration D2-EYI.

1.18.3 The other three helicopters continued operating until December 2017 when they were grounded and subjected to Bell's parking and storage programme. According to the logbooks, the three helicopters were shipped to South Africa around December 2019 after the current owner acquired them from Heli Malongo. They arrived with their valid export Certificates of Airworthiness and were assembled by the AMO. During their assembly, the three helicopters were all converted to air ambulances by installing APLS and EMS interior following STCs SR00235DE-D and SR00514DE-D in accordance with the Air-Methods Approval.

CONCLUSIONS

The upper pitch link clevis for the Orange main rotor blade was found to have fractured via fatigue. The fatigue originated at pitting corrosion, which was less than 0.001 inch deep. This fracture would have resulted in the Orange blade losing pitch control. The Orange universal bearing was seized as a result of corrosion with no notable amount of grease inside. The remaining universal bearings required atypically high and inconsistent amounts of torque to rotate. Wiring found tangled in fractured spar, and the extent of damage to the spar, indicated the Orange blade was the first to impact the cabin as a result of an atypical downward flapping movement.

1.18.4 **Oxygen and other gas cylinders** from SACAA CAR 2011

Part 138.05.6 *(1) If an aircraft engaged in an air ambulance operation is equipped with gas cylinders for medical purposes, the cylinders shall—*

(a) be carried in accordance with the provisions of part 92; and

(b) if the cylinders are inside the cabin, be positioned in such a way that no part of the fitment constitutes a hazard to any person inside the cabin, the pressure gauges are fitted and visible for use, and shut-off and change-over valves are readily accessible; or

(c) if the cylinders are positioned outside the cabin, be positioned in such a way that the in-line pressure gauges are visible for use and shut-off and change-over valves are installed inside the cabin.

(2) All portable gas cylinders shall be properly secured with approved devices during flight.

(3) All gas outlets shall be clearly marked for identification as to their function and gas supplied in accordance with the applicable SABS (South African Bureau of Standards) Code of Practice.

(4) All oxygen and medical gas cylinders used in an air ambulance operation—

(a) shall have an annual visual and a five-yearly hydrostatic inspection by a testing facility approved for the purpose by the Department of Labour.

(b) shall be marked with a sticker denoting approval for "return to service" and "next service due" date, which sticker shall be clearly visible to flight crew and medical personnel;

(c) shall, where applicable, bear a stamp of approval from an appropriately approved provider which stamp shall be clearly visible on each cylinder and certifying such cylinder as being approved.

(5) All oxygen and medical gas cylinders fixed in an air ambulance aircraft shall be maintained as per the manufacturer's specifications.

1.18.5 During helicopter assembly, the four PCL were sent to an external AMO for various non-distractive testing (NDT). The clevises were to be tested using magnetic particle inspection method and the PCL body would be tested with fluorescent penetration inspection. Copies of receiving inspection and dual inspection during installation of the affected clevises are attached as Annexure F & G, as per **CAR 2011, Part 43.04.8** Duplicate inspections of flight and engine controls:

(1) No person shall certify a control system component after the initial assembly, subsequent disturbance or adjustment of any part of such control system, unless—

(a) a duplicate safety inspection of the control system has been carried out; and

(b) the duplicate safety inspection is recorded and certified in the appropriate logbook or other maintenance record approved by the Director.

(2) A duplicate safety inspection authorised in terms of sub-regulation (1), shall consist of—

(a) an inspection by a person referred to in regulation 43.04.1 to certify the release to service of the control system after maintenance; and

(b) a second inspection carried out by another person who is a person referred to in sub-regulation (1) for an aircraft with a MCM in excess of 5700 kg, as prescribed in Document SA-CATS 43; or

(c) a second inspection carried out by another person who is a person referred to in sub-regulation (1) for helicopters with a MCM in excess of 3 175 kg, as prescribed in Document SA-CATS 43; or

(d) a second inspection carried out by another person who is a person referred to in sub-regulation (1) for an aircraft with a MCM below 5 700 kg and helicopters with a MCM below 3 175 kg, as prescribed in Document SA-CATS 43.

1.19. Useful or Effective Investigation Techniques

1.19.1 None.

2. ANALYSIS

2.1. General

From the available evidence, the following analysis was made with respect to this accident. This shall not be read as apportioning blame or liability to any particular organisation or individual.

2.2. Analysis

A. Personnel

2.2.1 The pilot was initially issued a Commercial Pilot Licence on 30 October 2009. His last CPL validation was on 25 November 2020 with an expiry date of 30 November 2021. The pilot had a total of 2680.3 hours on helicopters and 563.2 of those hours were on the helicopter type. He had a Class 1 aviation medical certificate which was issued on 26 June 2020 with an expiry date of 30 June 2021. The pilot had a Part 138 flight crew training certificate issued on 25 June 2020 with an expiry date of 30 June 2021 (Annexure A).

2.2.2 The operation was a one-pilot operation in terms of Part 127 of the CAR 2011, thus, there was no co-pilot or first officer in this commercial operation and none was required by the regulation.

2.2.3 The helicopter paramedic was a qualified Emergency Care Practitioner (ECP). He completed the Flight Crew Training programme for air ambulance services on 18 May 2020 with an expiry date of 31 May 2021 (Annexure B).

B. Weather

2.2.4 On the day of the accident, the helicopter was due to depart in the morning. However, as they normally flew under visual meteorological conditions (VMC), they waited for the conditions to improve to fly VFR. Around 0800Z, they decided that the weather had improved and that they could continue with the flight. Visibility was more than 10 kilometres (km) throughout their flight, and the sky was clear.

C. Machine

2.2.5 The accident helicopter was imported from Angola to South Africa by the National Airways Cooperation (NAC) in 2018. The records from Heli Malongo (previous operator) indicated that prior to being imported to South Africa, the accident helicopter was involved in an accident whilst in operation at the oil platform in Angola on 15 November 2013 and was substantially damaged. The helicopter was repaired and returned to service whilst in Angola.

2.2.6 Historically, the four helicopters operated in a harsh environment where levels of humidity were relatively high (oceanic areas) and there was a high content of corrosive elements (Calcium Ci and Chlorides [Cl]) which made it easier for the environment to oxidise with the metal material and cause weakness in its protective coating Cadmium (Cd), thus, initiating pitting corrosion. The Bell maintenance manual specifies that the PCL components must be subjected to a magnetic particle inspection NDT every 2500 airframe hours, and that only the rod section is to be subjected to FPI testing, as well as that the clevis must be subjected to MPI testing. The NDT tests conducted only considered manufacturer's practises and did not consider environmental and operational conditions. The PCL tested by Bell Engineering Laboratories (2017) found that the upper pitch link clevis for the Orange main rotor blade was fractured due to fatigue. The fatigue originated at pitting corrosion, which was less than 0.001 inch deep. This fracture would have resulted in the Orange blade losing pitch control. According to the records, the manufacturer – Bell, never made any recommendations to remedy the situation.

2.2.7 The investigators requested Laboratory for Microscopy & Microanalysis to conduct tests on the helicopter parts found at the accident site. The Final report was issued in April 2021; it concluded that the contributing factor to the origin of the crack (which ultimately caused the orange clevis to fail, and which resulted in the Orange blade's loss of pitch control and, thus, destroying the helicopter) was the corrosion pitting which propagated into a fatigue crack.

2.2.8 The accident site indicated that the accident was a result of an in-flight break-up, and the wreckage spanned along a radius or 500m.

D. Conclussion

2.2.9 From the results of the above tests, it is evident that the failure of the Orange clevis initiated the accident events, and there is no denying that the PCL did not contribute much in the bigger scheme of aerodynamics other than change the angle of attack of the M/R blade. The clevis and the bottom end rods are not painted (only the PCL body is painted) to protect them from harmful environmental elements because they have threads, instead they are coated with Cadmium plating for protection. The accident helicopter and the two remaining helicopters (Heli Malongo) were acquired in the same year, 2006, and they were operated around oceanic conditions from 2006 to 2017 in Angola.

2.2.10 Steel or steel alloy has a tendency to lose its structural intergrity if exposed to high humidity containing high volumes of calcium and chloride. The NDT method that Bell recommends is magnetic particles inspection with a minimum detectable limit ~10µm depth. This method has a shortcoming if one is testing the threaded area, it is difficult to differentiate between the base of thread and an initial crack. All the components that required NDT were tested during the assembly period.

2.2.11 The ZT-RRT clevis was subjected to NDT testing and released to service on 20 February 2020 (as per Annexure E). The laboratory results indicated that the Cadmium plating on all clevis' was compromised, and this made it possible for pitting corrosion to start due to tensile stress and compression loads the clevis is subjected to when the M/R blades are spinning.

2.2.12 Even though the pitch remains the same, the clevis is under severe strain which is caused by the blades spinning at 2500 revolutions per minute (RPM). This means that the clevis is in tension and compression 2500 times per minute. The cracks initiated on the opposite sides of the inner part of the threads, which is the smallest part; when the cracks expand, they move in a horizontal direction. If the technician conducting the test does not take this into consideration, they might think that the cracks are the extension of the thread. The laboratory results are clear that the initial cracks on the opposite sides occurred over an extended period. Only 60% - 70% of the cracks occurred on the day of the accident. The breakdown of the coating against harmful elements led to the initiation of the pitting corrosion which resulted in the cracks; this eventually resulted in the Orange clevis failure and, thus, loss of pitch control to the blade.

2.2.13 The Orange M/R blade was no longer synchronised with the operation of the main rotor blade and was free to follow any atypical movement. The Orange and Green M/R blades are mounted on the lower yoke, and it would be easier for the blade to flap downwards, while the other two on the upper yoke flapped upwards trying to maintain equilibrium. Because the PCL link was no longer controlling the pitch of the Orange blade, the Orange blade flapped downwards and inflicted severe damage to the airframe, resulting in the tail boom being severed. The tail boom and other airframe parts were severed by the Orange M/R blade; the pilot could not control the helicopter and it started to spin out of control. The helicopter lost height and crashed, and a post-impact fire destroyed the helicopter. All five occupants were fatally injured.

3. CONCLUSION

3.1. General

From the available evidence, the following findings, causes and contributing factors were made with respect to this accident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

To serve the objective of this investigation, the following sections are included in the conclusion heading:

- **Findings —** are statements of all significant conditions, events or circumstances in this accident. The findings are significant steps in this accident sequence, but they are not always causal or indicate deficiencies.
- **Causes —** are actions, omissions, events, conditions or a combination thereof, which led to this accident.

- **Contributing factors —** are actions, omissions, events, conditions or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the accident occurring, or would have mitigated the severity of the consequences of the accident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2. Findings

3.2.1 The pilot was initially issued a Commercial Pilot Licence (CPL) on 30 October 2009. His last licence validation was on 25 November 2020 with an expiry date of 30 November 2021. He was issued a Class 1 aviation medical certificate on 26 June 2020 with an expiry date of 30 June 2021.

3.2.2 The helicopter paramedic was a qualified Emergency Care Practitioner (ECP). He also completed the Flight Crew Training programme certificate for air ambulance services on 18 May 2010 with an expiry date of 31 May 2021.

3.2.3 The aircraft was issued a Certificate of Airworthiness on 30 June 2020 with an expiry date of 30 June 2021. The aircraft was issued a Certificate of Registration on 22 November 2019.

3.2.4 The last MPI (150-hour/1-year inspection) was carried out on 23 September 2020 at 7546.6 airframe hours. The aircraft had accumulated an additional 137.7 airframe hours in operation since the last MPI.

3.2.5 The helicopter was one of four helicopters that were operated by Heli Malongo from 2006 to 2017 in Angola and were used to ferry employees of an oil producing company between Heli Malongo heliport and Tombua-Landana offshore platform.

3.2.6 On 26 September 2016, one of the helicopters, registration D2-EYI, crashed in the Pacific Ocean and all six occupants were fatally injured. Angolan authorities, GPIAA, released a final accident report on 28 August 2018 which had safety recommendation(s). Annexure N indicates the recommendations that were directed at Bell Helicopters to consider and implement.

3.2.7 A post-accident examination which was conducted by Bell on D2-EYI helicopter accident was conducted by Bell Engineering Laboratories. Various components were tested such as main rotor hub, controls, blades and airframe components from model 430 operated by Heli Malongo, and their report 43017M-015EXT dated 14 August 2017 concluded that:

The upper pitch link clevis for the Orange main rotor blade was found to have fractured via fatigue. The fatigue originated at pitting corrosion, which was less than 0.001 inch deep. This fracture would have resulted in the Orange blade losing pitch control. No safety recommendation(s) were issued by Bell. The accident helicopter ZT-RRT examination found the same failure on the Orange blade clevis.

3.2.8 In 2018, the three remaining helicopters were grounded by Heli Malongo and were subjected to a storage (facility) programme IAW Bell 430 MM CH 10-18 for intermediate storage. On 12 December 2018, they were issued a valid export Airworthiness Certificate.

3.2.9 The three helicopters were shipped to South Africa with a valid export Airworthiness Certificate on 10 December 2019 and were received by their current operator (Annexure D).

3.2.10 During the helicopter assembly, the clevis and PCL body at 7730.5 hours were sent to an AMO and were subjected to a NDT magnetic particle testing IAW the manufacturer's instructions which had to be performed every 2500 hours. The results of the test dated 24 January 2020 indicated that there was "no defects found at time of inspection". The components life limit is 10000 hours in accordance with the manufacturer's limits

3.2.11 The NDT that was conducted only considered manufacturer's practises and did not consider the environmental (high level of humidity and chlorine) and operational context in which the helicopter was operated for more than 10 years.

3.2.12 The accident helicopter was issued a Certificate of Release to Service on 23 September 2020 by the Regulator with an expiry date of 23 September 2021 or at 7693.7 airframe hours, whichever occurs first.

3.2.13 The flight was conducted under the provisions of Part 138 of the CAR 2011 as amended. This was an emergency flight from Ultimate Heliport in Gauteng to Hillcrest Hospital in KwaZulu-Natal.

3.2.14 The operator was issued an AOC number CAA/G140D Part 127 with endorsement of Part 138 by the Regulator on 1 September 2020, with an expiry date of 31 May 2021.

3.2.15 The AMO that carried out the last maintenance inspection on the aircraft was issued an AMO approval certificate on 7 September 2020 with an expiry date of 31 May 2021.

3.2.16 After approximately 1.5 hours in-flight, whilst cruising at 725ft AGL, the helicopter started to spin uncontrollably, followed by a break-up in-flight while losing height rapidly. The helicopter subsequently impacted the ground and post-impact fire erupted, destroying the helicopter. All five occupants on-board were fatally injured.

3.2.17 The helicopter broke up in-flight following failure of the clevis which controls the pitch of the Orange blade. This resulted in the Orange blade not being synchronised with the other blades in the main rotor disc and that caused the Orange blade to flap down freely, damaging the airframe and severing the tail boom. Thereafter, the helicopter became uncontrollable and started to spin before it crashed, fatally injuring the occupants.

3.3. Probable Causes

3.3.1 The clevis on the pitch control lever of the Orange blade failed in-flight, resulting in the instability of the main rotor disc which, in turn, severed the most rear section of the tail boom. As a result, the main rotor blades subsequently failed. The combination of the severed most rear section of the tail boom and the main rotor failure resulted in the pilot losing control of the helicopter and, thus, the subsequent crash.
Corrosion fatigue/metal fatigue, mechanical failure and improper maintenance.

3.4. Contributory Factors

3.4.1 Failure to identify the fatigue crack on the clevis threaded section during a magnetic particle inspection as well as during the MPI.

4 SAFETY RECOMMENDATIONS

4.1. General

The safety recommendations listed in this report are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation and are based on the conclusions listed in heading 3 of this report. The AIID expects that all safety issues identified by the investigation are addressed by the receiving States and organisations.

4.2. Safety Recommendation/s

4.2.1 Following this accident and after the metallurgical analysis, the manufacturer, in collaboration with Transport Canada, issued Airworthiness Directive (AD) on 13 July 2021 (Annexure M), which required an initial special detailed inspection (SDI) of the main rotor pitch link clevises and detailed visual inspection (DVI) of the universal bearings, and rectification, as required. This AD also mandates a repetitive DVI of the main rotor pitch link clevises and universal bearings, and rectification, as required. Bell issued Alert Service Bulletin (ASB) 430-21-60 (Annexure L) to provide instructions for inspection and replacement of the affected parts. This AD is considered an interim corrective action and further AD action could follow.

4.2.1.1 It is recommended to the Director of Civil Aviation that in the interest of safety, the SACAA adopts and issue the same AD and make it mandatory to all operators and aircraft maintenance organisations to comply with, as per the manufacturer's maintenance instructions, for safe operation of aircraft.

4.2.1.2 It is also recommended that operators and aircraft maintenance organisations ensure that they adhere to the Civil Aviation Regulations requirements and the manufacturer's maintenance requirements as per this AD instructions.

4.2.1.3 It is also recommended that in the interest of safety, the manufacturer reviews the maintenance procedures relating to the NDT inspection of the main rotor clevis.

5. APPENDICES

5.1 Annexure A: Pilot's Part 138 flight crew training

5.2 Annexure B: Flight crew paramedic's Part 138 flight crew training

5.3 Annexure C: Heli Malongo copy of aircraft storage programme

5.4 Annexure D: Export Certificate of airworthiness issued in Angola

5.5 Annexure E: Magnetic particle inspection NDT results of all four clevises

5.6 Annexure F: Receiving Inspection of clevises

5.7 Annexure G: Installation dual inspection of clevises

5.8 Annexure H: NAC Air operating certificate (AoC)

5.9 Annexure I: Report; Laboratory for Microscopy & Microanalysis link

5.10 Annexure J: Report; Bell Engineering laboratories link

5.11 Annexure K: Conclusion; Rolls-Royce engine investigation report

5.12 Annexure L: Bell: Alert safety bulletin 430-21-60

5.13 Annexure M: TCCA: Airworthiness directive CF-2021-26

5.14 Annexure N: GPIAA safety recommendations to Bell Helicopter

This report is issued by:

Accident and Incident Investigations Division
South African Civil Aviation Authority
Republic of South Africa

Annexure A: Pilot's Part 138 Flight Crew Training Certificate

Certificate No:
ULHP 144/2020

CERTIFICATE OF ATTENDANCE

Has successfully completed the Part 138 Flight Crew Training Program for the

Gauteng Air Ambulance Service on 25 June 2020

Heath Mitchell
(Netcare Base Manager / Instructor)

Benedict Ledwaba
(Regional Operation Manager CCRS)

nac
AOC FO5644
N140D I/N 053 G141D

Expired: 30 June 2021

NETCARE 082911
24HR EMERGENCY MEDICAL ASSISTANCE

Annexure B: Pilot's Part 138 Flight Crew Training

Certificate No:

ULHP 079/2020

CERTIFICATE OF ATTENDANCE

[redacted]

Has successfully completed the Part 138 Flight Crew Training Program for the

Gauteng Air Ambulance Service on 18 May 2020

Heath Mitchell (Base Manager / Instructor)

Benedict Ledwaba (Deputy Head of EOC)

nac

AOC FO5644

N140D I/N 053 G141D

Expired: 31 May 2021

NETCARE 082911

24HR EMERGENCY MEDICAL ASSISTANCE

Annexure C: Heli Malongo Copy of Aircraft Storage Programme

Heli-Malongo — Task Summary: **171741-48**

Aircraft:	D2-EYS	S/N:	49126	Template:	B430	Customer:	HM - HELI-MALONGO

Origin:	Maint - Scheduled	Pos. Path:	...	SCHEDULED
ATA:	10-10-00 PARKING AND STORAGE	Parent Task:	...	

Skill Req.:	MAINTENANCE MALONGO	Shop Est.:	0.00 H	Created:	2017-12-08
Base:	MAL			DUE:	...

Task Description:

Comply with following Intermediate/Short term storage requirements per attached BHT 430 MM CH 10-00-00
Ensure fuel quality is clean prior to proceeding to run aircraft.
Add Brayco 599/ Win Air P/N 27002AECZ at proportion of 1.5 oz per quart of oil to XMSN oil and T/R G/B oil.
Depressive engines to run aircraft.
Start engines and operate them 5 minutes after reaching normal operating temps. AD
After running engines -preserve engines for storage.
Drain and preserve fuel system after ground runs complete. FP AD

Notes: Comply with additional steps of 430 MM CH 10-18 for intermediate storage. AD

Annexure D: Export Certificate of Airworthiness Issued in Angola

REPÚBLICA DE ANGOLA
MINISTÉRIO DOS TRANSPORTES
INSTITUTO NACIONAL DA AVIAÇÃO CIVIL

CERTIFICADO
de
NAVEGABILIDADE PARA EXPORTAÇÃO
CERTICATE OF AIRWORTHINESS FOR EXPORT

Nº06/CAE/12.12/2018

PELO PRESENTE DOCUMENTO SE CERTIFICA QUE A AERONAVE A SEGUIR IDENTIFICADA FOI INSPECCIONADA E A DATA DA EMISSÃO DESTE CERTIFICADO A MESMA FOI CONSIDERADA APTA PARA VOO, CONFORME A CONVENÇÃO SOBRE AVIAÇÃO CIVIL INTERNACIONAL, DE 7 DE DEZEMBRO DE 1944 E A LEGISLAÇÃO EM VIGOR:

THIS CERTIFIES THAT THE AIRCRAFT IDENTIFIED BELOW HAS BEEN EXAMINED AND ACCORDING TO THE ISSUANCE DATE OF THIS CERTIFICATE THE SAID AIRCRAFT WAS CONSIDERED AIRWORTHY PURSUANT TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION, DATED 7 DECEMBER 1944 IN ASSOCIATION WITH LEGISLATION IN FORCE:

Produto: Aircraft
Product

Motores: Rolls-Royce
Engines:
Modelo:RR 250-C40B
Model:
S/N # 1: CAE 844249 S/N # 2: CAE 844234

Helices:N/A
Propeller:
Modelo:N/A
Model:
S/N #1: N/A S/N # 2:N/A

Fabricante:Bell Helicopter Textron Canada
Manufacturer:
Modelo: 430
Model:
Número de Série: 49126
Serial Number:
Novo / New [ ] Usado / Used [X]

País de Destino:
Country to Which Exported: South Africa

Emitido em Luanda aos 30th de November, de 2018

GASPAR SANTOS
O DIRECTOR GERAL
GENERAL DIRECTOR

RUA MIGUEL DE MELO Nº 96, 6º ANDAR TEL.: 222-335936/8596 – FAX: 222 390529 – E-MAIL inavic@inavic.gov.ao

Annexure E: Magnetic Particle Inspection NDT Results of All Four Clevises

Cessna Authorized Independent NDI Facility

UNIT INSPECTION AVIATION SERVICES

"CESSNA (USA) AUTHORIZED FACILITY

SACAA CERTIFICATE OF APPROVAL NO. : M842

LANSERIA
TEL / FAX : (011) 701 3068

REPORT N29885

AIRCRAFT TEST REPORT / RELEASE CERTIFICATE

THIS CONSTITUTES AN OFFICIAL LOG BOOK ENTRY AND MUST BE AFFIXED IN THE APPROPRIATE LOG BOOK.

CLIENT EMPEROR AVIATION	ORDER EA 9560
LOCATION RAND AIRPORT	AIRCRAFT REG: ZS-RRT
IDENTIFICATION / DESCRIPTION ASSOCIATED PARTS	U.I.C. JOB NO. N29885

WORK / METHOD
NON DESTRUCTIVE TESTING INSPECTION - MAGNETIC PARTICLE TESTING - CARRIED OUT ON HELICOPTER ASSOCIATED PARTS AS PER YOUR REQUEST IN ACCORDANCE WITH NDT STANDARD TESTING PRACTICES ASTM E 1444(M-16e1 REF)

QTY 4 CLEVIS ASSY'S P/N 430-010-432-101 S/N U567
S/N U569
S/N U568
S/N U572

EQUIPMENT USED : HELIX MAGNETIC YOKE TESTING UNIT
CONTRAMAG MAGNETIC BENCH UNIT.

NOTE : NDT INSPECTIONS CARRIED OUT AS PER YOUR ORDER / REQUEST DO NOT REPLACE / SUBSTITUTE ANY MANUFACTURERS S/B'S, AD'S OR SERVICE SCHEDULES.*

RESULTS / REMARKS NO RECORDABLE DEFECTS FOUND AT TIME OF INSPECTION	CRITERIA / MANUAL USED REPORT ALL DEFECTS/CRACKS ETC.
INSPECTED BY N. REYNEKE	SIGNATURE

I HEREBY CERTIFY THAT THE ITEMS MENTIONED ABOVE HAS/HAVE BEEN TESTED IN ACCORDANCE WITH THE REQUIREMENTS PRESCRIBED IN THE MANUAL OF PROCEDURE SUBMITTED FOR THE ISSUE OF CERTIFICATE NO. M842

ACCOUNTABLE MANAGER

DATE : 24/01/2020

STAMP

Annexure F: Receiving Inspection

EMPEROR AVIATION

REG NO: 2012/147938/07
VAT NO: 4580262477

EMPEROR AVIATION (PTY) LTD
P.O.BOX 18006
RAND AIRPORT
GERMISTON
1449

Purchase Order

Date	24/01/2020
Page	1
Document No	EA9560

UNIT INSPECTION AVIATION SERVICES

Deliver to
HANGAR 23
LANSERIA AIRPORT

Account	Your Reference	Tax Exempt	Tax Reference	Sales Code	Delivery	
I001	WA3022 ZT-RRT DEF. 29	N			24/01/2020	Exclusive

Code	Description	Quantity	Unit	Unit Price	Disc%	Tax	Nett Price
000	MPI on the following: 4 X Clevis PN: 430-010-432-101 SN: US67; US69; US68; US72	1.00				15.00%	0.00

9560

EMPEROR AVIATION
RECEIVING INSPECTION

DATE	29 JAN 2020
NAME	
SIGN	

received
29 JAN 2020
UI DN: 9220

Received in good order

Signed ______ Date 24 JAN 2020

Sub Total		0.00
Discount @	0.00%	0.00
Amount Excl Tax		0.00
Tax		0.00
Total		0.00

Annexure G: Installation Dual Inspectection of Four Clevis

RECTIFICATION	DATE	HOURS	NAME	SIGN
TOOL CHECK:	20 FEB 20		C. HEATH	[signature/stamp]
TORQUE WRENCH S/N: JB13				
EXP. DATE: 14 MAR 2020				
COMPONENT REMOVED:				
PART NO SERIAL NO				
410-010-411-105/107 U568; U569; U567; U5[illegible]	20 FEB 20		C. HEATH	[signature/stamp]
COMPONENT INSTALLED				
PART NO SERIAL NO				
410-010-411-105/107 U5[illegible]; U5[illegible]; U569; U572	20 FEB 20		C. HEATH	[signature/stamp]

ENGINEERS SIGNATURE:	MAINTENANCE MANUAL REF.	DUAL INSPECTION:
[signature/stamp]	CRC #66D	DATE: 17-02-2020
DATE:- 20 FEB 2020		DEF. CLOSING SIGATURE: [signature/stamp]

Annexure H: NAC Air Operating Certificate (AoC)

OPERATING CERTIFICATE

PART 127

State of the Operator **SOUTH AFRICA**		
Issuing Authority **SOUTH AFRICAN CIVIL AVIATION AUTHORITY**		
AOC No: CAA/N140D	Certificate #: FO 14681	Operator's Address:
Expiry Date: 31 MAY 2021	Name of Certificate Holder: NATIONAL AIRWAYS CORPORATION (PTY) LTD T/A NAC Is the holder of air service licences N140D, I/N053 and G141D	P.O. Box 293 Lanseria 1748 South Africa Telephone: +27 11 312 0360 Fax: +27 86 402 5582 Cell: +27 72 480 0937 Jaco.deklerk@nac.co.za
Main Base of Operation: Block B, Hangar X Grand Central Airport New Road Midrand South Africa		

The above holder of this certificate has been authorised to operate air service(s) in terms of the above license(s) held in accordance with-
*the attached operations specifications;
*the provisions of Part 127 of the Civil Aviation Regulations of 2011;
*the provisions of the Air Service Licensing Act of 1990 (Act 115/1990) and the International Air Services Licensing Act of 1993 (Act 60/1993) as applicable.

Date of Issue: 01 September 2020	[signature]	Simon Segwabe Executive: Aviation Safety Operations
Issued at: MIDRAND SOUTH AFRICA	SIGNATURE	NAME AND TITLE
	EXECUTIVE: AVIATION SAFETY OPERATIONS	

This certificate and its annex was issued without any alteration or erasure CAA/FOD/AOC0000003149

CAA/FOD/AOC
0000003149

FO NO: 14681

Annexure I: Report; Laboratory for Microscopy & Microanalysis Link:

https://caacoza-my.sharepoint.com/:b:/g/personal/mvemver_caa_co_za/EaqogqaJ3ihGnj3dPkDPmVAB9iQjrhnj8JqByK8u_1rghw?e=vdOPn4

Annexure J: Report; Bell Engineering Laboratories Link:

https://caacoza-my.sharepoint.com/:b:/g/personal/mvemver_caa_co_za/EdFfLCr1S3RMpv8WoFXI0LsBgJVLvmOdXqxE5YKtIiYxbA?e=162W3S

Annexure K: Conclussion; Rolls-Royce Engine Investigation Report

Rolls-Royce Engine Investigation Report

Wreckage Exam Date: 28 January 2021
Wreckage Exam Location: Rand Airport, NAC
Aircraft Type: Bell 430
Aircraft Reg: ZT-RRT
Engine Model: M250-C40B
Engine S/N: #1 844249
#2 844234
Engine Rating: 715 SHP each (takeoff)

The wreckage exam was conducted on 28 January 2021 under the supervision of the South African CAA. Also in attendance were technicians from NAC and an ASI from Bell. The aircraft was recovered to the NAC hangar at the Rand Airport (South Africa). The wreckage was disintegrated into various sized items due to large impact forces and a post-crash fire. The engines were identified and after the initial inspection, both engines were transported to the adjacent engine shop for further teardown examination. The engine logbooks were reviewed and copies retained in the Rolls-Royce Air Safety Investigation file. No obvious anomalies were observed in the logbooks.

Aircraft after recovery to NAC Facility

Executive Summary: No abnormalities were observed during the engine exam which would affect engine operation during the event. The damage noted to both power turbine sections was consistent with a loss of load during the impact sequence and subsequent overspeed of the power turbine rotors. Multiple rotational and operational signatures were observed in both engines which was consistent with engine operation during the accident sequence.

Rolls-Royce Corporation
7715 North Perimeter Road
Indianapolis, IN 46241

Accident Hotline: +1.317.230.6630
airsafetyinvestigationindy@rolls-royce.com

Annexure L: Bell: Alert Safety Bulletin 430-21-60

BELL

A Textron Company

ALERT SERVICE BULLETIN **430-21-60**

13 July 2021

MODEL AFFECTED: **430**

SUBJECT: **MAIN ROTOR PITCH LINK ASSEMBLY CLEVIS AND UNIVERSAL BEARING, INSPECTION OF.**

HELICOPTERS AFFECTED: **Serial numbers 49001 through 49129.**

COMPLIANCE:

PART I: Within 25 flight hours or 30 days whichever comes first after the release date of this bulletin.

PART II: Within 50 flight hours and every 50 flight hours thereafter after accomplishment of PART I.

PART III: Within 150 flight hours and every 150 flight hours thereafter after accomplishment of PART I.

DESCRIPTION:

This ASB mandates a one-time magnetic particle inspection of the main rotor pitch link assembly clevis 430-010-432-101, a one-time inspection of the universal bearing 212-010-412-001, a recurring visual inspection of the clevis and a recurring inspection of the universal bearing.

APPROVAL:

The engineering design aspects of this bulletin are Transport Canada Civil Aviation (TCCA) approved.

CONTACT INFO:

For any questions regarding this bulletin, please contact:

Bell Product Support Engineering
Tel: 1-450-437-2862 / 1-800-363-8023 / productsupport@bellflight.com

ASB A 430-21-60
Page 1 of 11
Approved for public release.

Annexure M: TCCA: Airworthiness Directive CF-2021-26

AD Number: CF-2021-26

AIRWORTHINESS DIRECTIVE

This Airworthiness Directive (AD) is issued pursuant to Canadian Aviation Regulation (CAR) 521.427. No person shall conduct a take-off or permit a take-off to be conducted in an aircraft that is in their legal custody and control, unless the requirements of CAR 605.84 pertaining to ADs are met. Standard 625 - Aircraft Equipment and Maintenance Standards Appendix H provides information concerning alternative means of compliance (AMOC) with ADs.

Number:

CF-2021-26

Effective Date:

9 August 2021

ATA:

62

Type Certificate:

H-88

Subject:

Main Rotor – Pitch Link Assembly Clevis Fracture

Applicability:

Bell Textron Canada Limited (Bell) model 430 helicopters, serial numbers 49001 through 49129.

Compliance:

As indicated below, unless already accomplished.

Background:

In January 2021, a model 430 helicopter experienced an in-flight failure of a main rotor pitch link clevis resulting in loss of control of the helicopter and fatal injury to the five occupants on-board. The main rotor pitch link clevis part number (P/N) 430-010-432-101 fractured at the exposed thread area above the nut and the fracture was consistent with fatigue damage. A similar accident previously occurred in September 2016 on a model 430 helicopter where the main rotor pitch link clevis was found to have fractured at the neck area via fatigue damage that originated at a corrosion pit.

Inspection of the failed part from the 2021 accident determined that the universal bearing P/N 212-010-412-001 of the main rotor pitch link assembly was found with excessive wear and had increased resistance to rotation. Restriction in freedom of movement of the universal bearing can cause increased loads on the main rotor pitch link assembly and subsequent fatigue failure of the clevis prior to its life limit. The accident investigation is still ongoing.

This condition, if not corrected, could lead to crack initiation at the main rotor pitch link clevis neck or threaded area and consequent failure of the main rotor pitch link, resulting in loss of control of the helicopter.

To address this unsafe condition, this AD requires an initial special detailed inspection (SDI) of the main rotor pitch link clevises and detailed visual inspection (DVI) of the universal bearings, and rectification, as required. This AD also mandates a repetitive DVI of the main rotor pitch link clevises and universal bearings, and rectification, as required. Bell issued Alert Service Bulletin (ASB) 430-21-60 to provide instructions for inspection and replacement of the affected parts.

This AD is considered an interim corrective action and further AD action could follow.

Corrective Actions:

For the purpose of this AD, the following definitions apply:

The ASB: Bell ASB 430-21-60, Basic Issue, dated 13 July 2021, or later revisions approved by the Chief, Continuing Airworthiness, Transport Canada.

Serviceable part: A serviceable main rotor pitch link clevis is a new main rotor pitch link clevis or a main rotor pitch link clevis that has been inspected in accordance with the requirements of this AD and found acceptable. A serviceable universal bearing is a new universal bearing or a universal bearing that has

Canada

been inspected in accordance with the requirements of this AD and found acceptable.

Part I – Initial Inspection and Rectification

Within 25 hours air time or 30 days, whichever occurs first, from the effective date of this AD, accomplish the following, in accordance with the Accomplishment Instructions of Part I of the ASB:

A. Perform a DVI of the main rotor pitch link clevises and rod ends for wear and damage, and rectify any defect as required.
B. Perform a DVI of the universal bearings for signs of binding or stiffness, wear, damage, looseness, excess axial and radial play, and rectify any defect as follows:
   i. For each main rotor pitch link assembly P/N 430-010-411-105/-107 that has accumulated 5000 hours air time or less and has an associated universal bearing P/N 212-010-412-001 that is found to be unserviceable: replace the universal bearing with a serviceable part.
   ii. For each main rotor pitch link assembly P/N 430-010-411-105/-107 that has accumulated more than 5000 hours air time and has an associated universal bearing P/N 212-010-412-001 with signs of binding or stiffness: replace both the universal bearing and the main rotor pitch link clevis with serviceable parts.
   iii. For each main rotor pitch link assembly P/N 430-010-411-105/-107 that has accumulated more than 5000 hours air time and has an associated universal bearing P/N 212-010-412-001 that is found to be unserviceable but with no signs of binding or stiffness: replace the universal bearing with a serviceable part. For a main rotor pitch link assembly that has accumulated more than 5000 hours air time, the associated main rotor pitch link clevis can remain in service until the current life limit of the main rotor pitch link assembly is reached provided the associated universal bearing is found serviceable with no signs of binding or stiffness.
   iv. Purge grease the bearings of each universal bearing ensuring all four grease fittings allow for grease purging.
C. Perform a magnetic particle inspection (MPI) of the main rotor pitch link clevises to detect cracks, and replace clevises that have signs of cracking.
D. If the main rotor pitch link clevis is found serviceable following the MPI, replace missing cadmium plating by carrying out selective brush cadmium plating and apply chromate conversion coating.

Part II – Repetitive Inspection and Rectification

Following completion of Part I of this AD, accomplish the following:

A. At intervals not to exceed 50 hours air time, perform a DVI of the main rotor pitch link clevises for corrosion and mechanical damage, and rectify any defect as required, in accordance with the Accomplishment Instructions of Part II of the ASB. If any suspected defects are found as a result of the DVI, perform a MPI of the affected main rotor pitch link clevises in accordance with Corrective Action Part I.C and I.D of this AD.
B. At intervals not to exceed 150 hours air time, perform a DVI of the universal bearings for signs of binding or stiffness, wear, damage, looseness, excess axial and radial play, and rectify any defect, in accordance with the Accomplishment Instructions of Part III of the ASB and Corrective Action Part I.B of this AD.

Authorization:

For the Minister of Transport,

ORIGINAL SIGNED BY

Jean Grenier
Acting Chief, Continuing Airworthiness
Issued on 26 July 2021

Contact:

Audrey Vézina-Manzo, Continuing Airworthiness, Ottawa, telephone 888-663-3639, facsimile 613-996-9178 or e-mail TC.AirworthinessDirectives-Consignesdenavigabilite.TC@tc.gc.ca or any Transport Canada Centre.

4.2 BELL HELICOPTER SHALL:

1) Review, in functional terms, the project diagram of the main rotor pitch link clevis for the orange blade of the aircrafts type Bell, model Bell430, of its manufacture;
2) Evaluate and, if possible, review the inspection and maintenance procedures related to the operation and main rotor components replacement, in particular for the main rotors pitch link clevis for the blades and the respective universal bearings;
3) Review, in terms of safety, its recommendations issued on the requirements being observed with relation to the established time margins (10.000 h) for the main rotor pitch link clevis for the blades replacement of the aircraft type Bell, model Bell430;
4) Conceive instruments of imperative character, that obligate to carry out, in periods of determined times, Non DestructiveTests (NDT) to the main rotors pitch link clevis for the blades replacement of the aircraft type Bell, model Bell430;
5) Issue safety recommendations to the aircrafts Bell430, that make possible the identification of eventual evidences of the universal bearing malfunctioning, establishing also the respective tolerance margins, taking in account the identified deficiencies values.