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FINAL INVESTIGATION REPORT ON ACCIDENT INVOLVING GOVERNMENT OF CHHATTISGARH AGUSTA A109E HELICOPTER VT-CHG AT RAIPUR AIRPORT ON 12 MAY 2022.

GOVERNMENT OF INDIA
MINISTRY OF CIVIL AVIATION
AIRCRAFT ACCIDENT INVESTIGATION BUREAU

FOREWORD

In accordance with Annex 13 to the Convention on International Civil Aviation Organization (ICAO) and Rule 3 of Aircraft (Investigation of Accidents and Incidents), Rules 2017, the sole objective of the investigation of an Accident/Incident shall be the prevention of accidents and incidents and not to apportion blame or liability. The investigation conducted in accordance with the provisions of the above said rules shall be separate from any judicial or administrative proceedings to apportion blame or liability.

This document has been prepared based upon the evidences collected during the investigation, opinion obtained from the experts and laboratory examination of various components. Consequently, the use of this report for any purpose other than for the prevention of future accidents or incidents could lead to erroneous interpretations.

Contents

GLOSSARY

A/C	Aircraft
A/F	Airframe
AAI	Airport Authority of India
AAIB	Aircraft Accident Investigation Bureau
AGL	Above Ground Level
AME	Aircraft Maintenance Engineer
AMSL	Above Mean Sea Level
ANSV	Agenzia Nazionale Per La Sicurezza Del Volo
AOP	Air Operator Permit
ARC	Airworthiness Review Certificate
ASDA	Accelerate Stop Distance Available
ATC	Air Traffic Control
ATO	Approved Training Organization
AUW	All Up Weight
AVSEC	Aviation Security
BA	Breathe Analyzer
BSI	Borescope Inspection
C.G	Centre of Gravity
CAD	Civil Aviation Department
CAM	Continuing Airworthiness Manager
CAR	Civil Aviation Requirement
CAS	Crew Alerting System
CAS	Computed Air Speed
CCTV	Closed-Circuit Television
CFS	Chief of Flight Safety
CHPL	Commercial Helicopter Pilot License
CoFS	Chief of Flight Safety
COO	Chief Operating Officer
CPL	Commercial Pilot License
CRM	Crew Resource Management
CRS	Certificate of Release to Service
CT	Compressor Turbine
CVDR	Cockpit Voice and Data Recorder
CVR	Cockpit Voice Recorder
CW	Clock-Wise
DAU	Disc-Assembly Unit
DFDR	Digital Flight Data Recorder
DGCA	Directorate General of Civil Aviation
DI	Daily Inspection
DME	Distance Measuring Equipment
DOACG	Directorate of Aviation, Chhattisgarh
EAPS	Engine Air Particle Separator
ECS	Environment Control System

EDS	Energy Dispersive Spectroscopy
EEC	Engine Electronic Controller
EEPROM	Electrically Erasable Programmable Read Only Memory
ELT	Emergency Locator Transmitters
EMER	Emergency
FAA	Federal Aviation Administration
FDAP	Flight Data Analysis Program
FDM	Flight Data Monitoring
FDR	Flight Data Recorder
FDTL	Flight Duty Time Limitation
FFS	Full Flight Simulator
FLT	Flight
FOQA	Flight Operational Quality Assurance
FRB	Flight Report Book
FRTOL	Flight Radio Telephony Operator's License
FTD	Flight Training Device
FTR	Force Trim Release
GoCG	Govt. of Chhattisgarh
GPS	Global Positioning System
HIRL	High Intensity Runway Lights
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organization
IDS	Integrated Display System
ILS	Instrument Landing System
IMD	Indian Meteorological Department
IR	Instrument Rating
IST	Indian Standard Time
KIAS	Indicated Air Speed in Knots
KT/Kts.	Knots
L.H	Left Hand
LDA	Landing Distance Available
LE	Leading Edge
LH	Leonardo Helicopters
LOC	Localizer
LTE	Loss of tail rotor effectiveness
MEK	Methylethylketone
MEL	Minimum Equipment List
MET	Meteorology
METARs	Meteorological Aerodrome Report
MGB	Main Gear Box
MHz	Mega Hertz
MM	Maintenance Manual
MPM	Maintenance Planning Manual
MPOG	Minimum Pitch on Ground

MR	Main Rotor
MRB	Main Rotor Blades
MRH	Main Rotor Head
NM	Nautical Miles
NOSIG	Not Significant
NSOP	Non-Schedule Operator
OEM	Original Equipment Manufacturer
OM	Operations Manual
P/N	Part Number
PF	Pilot Flying
PIB	Permanent Investigation Board
PIC	Pilot in Command
PM	Pilot Monitoring
PPC	Pilot Proficiency Check
PRES	Pressure
PT	Power Turbine
QM	Quality Manager
QNH	Nautical Height
RFM	Rotor Flight Manual
RPM	Revolution Per Minute
RTR	Radio Telephony Restricted
RWY	Runway
SALS	Simple Approach Lighting System
SAS	Stability Augmentation System
SB	Service Bulletin
SEM	Scanning Electron Microscope
SOP	Standard Operating Procedure
TGB	Tail Gear Box
TODA	Take Off Distance Available
TORA	Take Off Run Available
TQ	Torque
TR	Thrust Reverser
TRE	Type Rated Examiner
TRI	Type Rated Instructor
TSB	Transport Safety Board, Canada
UTC	Coordinated Universal Time
VARP	Raipur Airport
VERP	Raipur Airport
VHF	Very High Frequency
VOR	Very High Frequency Omni Range
WGS	World Geodetic System
WOW	Weight on Wheels
WR	Western Region
Wx	Weather

Final Investigation Report on Accident to Government of Chhattisgarh Agusta A109E helicopter VT-CHG at Raipur Airport on 12 May 2022			
1.	Aircraft	Type	Agusta A109E
		Nationality	Indian
		Registration	VT-CHG
2.	Owner		Directorate of Aviation, Government of Chhattisgarh
3.	Operator		
4.	Pilot in Command		CPL (H) holder
5.	Co-Pilot		CPL (H) holder
6.	No. of Persons on board		02
7.	Date & Time of Accident		12 May 2022, 1547 UTC
8.	Place of Accident		Raipur Airport
9.	Co-ordinates of Accident Site		21° 11' 04" N, 81° 44' 36" E
10.	Last point of Departure		Raipur Airport
11.	Intended landing place		Raipur Airport
12.	Type of Operation		Check Flight
13.	Phase of operation		Landing
14.	Type of Occurrence		System/Component Failure or Malfunction (Non-Powerplant) (SCF-NP) and Loss of Control in Flight (LOC-I).
15.	Extent of Injuries		Both person on board received Fatal Injury

(All the timings in this report are in UTC unless otherwise specified)

SYNOPSIS

On 12 May 2022, Government of Chhattisgarh Agusta A109E helicopter VT-CHG while operating a check flight met with an accident at Raipur airport. The check flight (Night route check) was conducted by a DGCA examiner and CHPL holder on type who was flying as PIC along with the company pilot holding CHPL on type flying as co-pilot.

The flight for night route check of the company pilot was scheduled with a DGCA examiner on type who was flying for another organisation based in Delhi. The helicopter after taking necessary clearances from ATC, took-off from Raipur airport. After departure from Raipur when the helicopter was about 20 Nm from Raipur, the crew informed ATC, Raipur that they will be returning to Raipur due to technical. The crew identified reduction in rudder effectiveness. The crew requested priority landing and informed that they will carry out low pass over runway first and then land. The crew however reported all operations normal. Accordingly, the ATC provided necessary clearances to the helicopter and cleared for landing on runway 24. When the helicopter was on finals runway 24, the crew informed ATC that they have better control of the aircraft and they will carry out landing in this approach itself. However, when they were close to the ground they decided against landing and informed ATC that they will go around. Accordingly, they discontinued the approach and carried out a go around (low pass over runway). The crew thereafter informed that they will land after the departure of scheduled aircraft which is in sequence for departure. After departure of the scheduled aircraft, the crew made an attempt to land but could not do so and carried out go around to make another approach.

During this approach the helicopter landed on runway 24 and after touch down, the helicopter rolled for about 13 seconds before it lifted up again and started yawing towards right. Thereafter, the helicopter lost control and started spinning to the right while gaining height. The helicopter entered into uncontrolled spin in clockwise direction during which it climbed to about 1680 feet AMSL. Thereafter, it started descending while spinning and crash landed near taxiway A of the airport beside runway. Both the crew received fatal injuries and the helicopter was destroyed.

The occurrence was classified as Accident as per the Aircraft (Investigation of Accidents and Incidents) Rules, 2017. DG, AAIB ordered an investigation to identify the probable cause(s) and contributor factor(s) leading to the accident vide Order No. INV-11011/08/2022-AAIB dated 17.05.2022.

Initial notification of the occurrence was sent to concerned states along with ICAO as per requirement of ICAO Annex 13 and state(s) appointed Accredited Representative and Technical Advisor(s) to participate in the investigation.

Unless otherwise indicated, recommendations in this report are addressed to the regulatory authorities of the State having the responsibility for the matters with which the recommendation is concerned. It is for those authorities to decide what action is taken.

1. FACTUAL INFORMATION

1.1 History of flight

On 12 May 2022, night flying sorties were planned on A109E helicopter VT-CHG as part of night recency checks for the two company pilots qualified on type. The first flight was for the night route check of the chief pilot of the company with the senior pilot of the company (deceased pilot) who was also an examiner on type. The second and subsequent flight was night route check and night PPC of the senior company pilot with a DGCA examiner on type from another organisation based in Delhi.

The DGCA examiner had flown from Delhi to Raipur on same day to carry out the night checks of deceased company pilot and for other tasks as requested by the Directorate of Aviation, Government of Chhattisgarh. The helicopter is generally positioned at company helipad at Raipur Police Line ground where the operator is having their hangar and base. Before operating the flight, the deceased company pilot carried out the walk around inspection of the helicopter and no abnormality was observed by the crew. As planned, the helicopter took-off at approximately 1300 UTC from police line ground helipad for the night check flight of the chief pilot with the deceased company pilot on board. After about one hour of check flight, the helicopter landed at Raipur airport and taxied to the company dispersal at Raipur Airport where the DGCA examiner was waiting. No abnormality was observed by the crew during this flight. The crew did a running changeover i.e., the chief pilot deboarded the helicopter and DGCA Examiner boarded the helicopter with rotors running. The chief pilot meanwhile left airport and returned home. As per the procedure, the company pilot was co-pilot and the DGCA examiner was PIC for this flight. The co-pilot was occupying the right seat whereas the PIC was occupying the left seat. The helicopter was under the control of the deceased company pilot i.e., the company pilot was the pilot flying (PF) and the examiner was the pilot monitoring (PM). The helicopter taxied out of the state dispersal and after taking necessary clearances from Raipur ATC, took-off from runway 24 at 1457 UTC. After about 10 minutes of take-off, the crew felt some problem in rudder (tail rotor) effectiveness and at 1505 UTC, while the aircraft was about 20 Nm from Raipur, they informed ATC Raipur that they will be returning to Raipur due technical and land back. From this time onwards the PIC took over the controls and was the PF. The ATC acknowledged the same and asked the crew to report when 15 Nm inbound Raipur and further asked altitude. The crew informed that they are maintaining 3100 feet altitude and will descend to 2000 feet and are now 18 Nm from Raipur. The crew then decided that they will do an overshoot over runway first to ascertain the speed upto which the tail rotor effectiveness is sustainable and then carry out landing later. Accordingly, at 1507 UTC, the crew informed ATC that they will do an overshoot (low pass over runway) first and then make a landing. The crew further informed ATC that there might be a problem in helicopter vacating the runway after landing and may end up blocking the runway. The crew also asked ATC to inform the chief pilot of the company to arrange towing arm for towing the helicopter from runway. The co-pilot called the chief pilot over phone to brief about the situation and requested to arrange for towing arm. Thereafter, at 1515 UTC, the crew informed ATC that the airfield is in sight and they will make a low pass over runway to adjust the speed for landing. Accordingly, ATC gave clearance to the helicopter for runway 24 and informed winds as 200^{o}/04 Kts. However, at 1520 UTC, the crew then informed ATC that they are comfortable now and will be making an approach landing on this attempt itself. The ATC cleared the helicopter to land. Meanwhile, there was a scheduled flight which was ready for departure but the ATC asked the scheduled flight to standby in order to facilitate landing of VT-CHG. The crew then decided otherwise and informed ATC that they will carry out go around and allow the scheduled aircraft to depart first. Accordingly, the helicopter did a low pass over runway and carried out go around. At 1522 UTC, the ATC then asked VT-CHG to confirm all operations normal to which the crew replied all operations are normal but there is little rudder problem so they will land after the departure of two scheduled aircraft (one ready to depart and one to start taxi) in case there is hold up on runway. The ATC then asked the helicopter to report endurance and the crew informed that they have one hour of endurance. At 1527 UTC, the ATC then informed the crew that one aircraft is ready for taxi and another aircraft will be ready by another 20 to 25 minutes. The crew informed ATC that they will land after the departure of the aircraft which is ready for taxi. Meanwhile, the chief pilot along with chief engineer of the company with required tool reached Raipur Airport.

At 1533 UTC, the crew informed ATC that they are visual with the scheduled aircraft taking off and they will position the helicopter for finals. At 1535 UTC, the crew informed that they are on finals for runway 24. The ATC gave landing clearance to the helicopter and informed winds as 170^{o}/05 kts. However, the crew informed ATC that they are again going around. The ATC instructed VT-CHG to report when left downwind runway 24 and asked intention to which the crew replied that they will make an attempt to land during this approach. At 1539 UTC, the crew reported finals runway 24 and the ATC cleared the aircraft to land informing winds as 160^{o}/05 kts. The helicopter landed at this approach and touched down on runway 24. During the landing run the helicopter nose was observed to have slightly yawed towards right. However, after about 13 seconds of rolling after touchdown, the helicopter suddenly lifted-up again and started to spin in clockwise direction. The helicopter kept on gaining height with rapid spin and got out of control. After reaching to a height of about 1680 feet AMSL it started descending rapidly while spinning and impacted the ground at around 1547 UTC. The helicopter crashed near taxiway A of the airport beside runway (Refer fig. 1). The fire and ambulance for rescue immediately reached the site. Both the crew were rescued from the helicopter and were rushed to the hospital. Both the crew received fatal injuries and were declared brought dead by the hospital. The runway remained closed for about 25 minutes due to rescue operation and inspection of runway and operational area.

Fig 1. Google map location of accident site.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	02	Nil	Nil
Serious	Nil	Nil	Nil
Minor	Nil	Nil	Nil

1.3 Damage to aircraft

The helicopter was destroyed in the accident. Details of helicopter damages are given in para 1.12 of this report.

1.4 Other damage

There was no other damage.

1.5 Personnel Information

1.5.1 Pilot in Command (DGCA Examiner)

Date of Birth	22-04-1963
License	CPL(H)
Date of Issue	28-04-2008
Valid up to	27-04-2023
Category	Helicopter .
Class	Single/Multi Engine
Date of Class I Med. Exam.	03-03-2022
Class I Medical Valid up to	10-09-2022
Date of issue FRTOL License	28-04-2008
FRTO License Valid up to	27-04-2023
Endorsements as PIC	SA 316/315, A109E
Total flying experience	9456:00 Hrs
Total flying experience on type (A109 E)	2321:00 Hrs
Last Flown on type	10.05.22, Flying Time: 01:55 Hrs
Total flying experience during last 1 year	389:05 Hrs
Total flying experience during last 6 Months	171:25 Hrs
Total flying experience during last 90 Days	83:55 Hrs
Total flying experience during last 30 days	32:05 Hrs
Total flying experience during last 07 Days	12:20 Hrs
Total flying experience during last 24 Hours	NIL
Rest period before flight	22 Hrs (Approx.)
Whether involved in Accident/Serious Incident earlier	NO
Date of latest Flight Checks and Ground Classes	IR/PPC on 15.02.2022 GROUND CLASS on 02.03.2022

The PIC was a DGCA examiner on type. The PIC was flying for other company, M/s Himalaya Putra Pvt. Ltd. which is based in Delhi. The PIC had flown to Raipur from Delhi on the same day (12.05.2022) to impart Route check (Night) to the co-pilot as per the request made by the Government of Chhattisgarh to M/s Himalaya Putra Pvt. Ltd. vide e-mail dated 12.05.2022.

1.5.2 Co-Pilot (Senior Company pilot)

Date of Birth	11/08/1966
License	CPL(H)
Date of Issue	29/08/2005
Valid up to	05/08/2025
Category	Helicopter
Class	Multi Engine, Land
Date of Class I Med. Exam.	22/01/2022
Class I Medical Valid up to	29/07/2022
Date of issue FRTOL License	29/08/2005
FRTO License Valid up to	05/08/2025
Endorsements as PIC	Allouette III/Chetak, Bell 412, Agusta 109E
Total flying experience	6189 hrs
Total flying experience as PIC on type (A109 E)	2014 hrs
Last Flown on type	11/05/2022
Total flying experience during last 1 year	204 hrs as on 11/05/2022
Total flying experience during last 6 Months	125 hrs as on 11/05/2022
Total flying experience during last 90 Days	56 hrs as on 11/05/2022
Total flying experience during last 30 days	24 hrs as on 11/05/2022
Total flying experience during last 07 Days	13:25 hrs as on 11/05/2022
Total flying experience during last 24 Hours	02:47 hrs approx
Rest period before first flight	23:18 hrs approx
Whether involved in Accident/Serious Incident earlier	NO
Date of latest Flight Checks and Ground Classes	As given below

Type of License/ Rating	**Valid From**	**Valid Till**
CHPL	06/08/20	05/08/25
FRTOL	06/08/20	05/08/25
RTR (A)	06/05/12	LIFE TIME
ENGLISH PROFICIENCY	31/03/11	LIFE TIME
I/R	13/01/22	12/01/23
PPC	14/12/21	03/08/22
ROUTE CHECK (NIGHT)	25/11/21	24/05/22
DANGEROUS GOODS TRAINING	24/09/21	31/10/23
CRM & SURVIVAL TRAINING	24/06/21	23/06/22

SPECIFIC GROUND TRAINING	24/06/21	23/06/22
GROUND REFRESHER TRAINING (Module 1)	21/03/22	20/03/23
GROUND REFRESHER TRAINING (Module 2)	22/03/22	21/03/23
MEDICAL (CAR SEC-5 SERIES F) PART-3	22/03/22	21/03/23
AVSEC	05/11/20	04/11/22
DI (PREFLIGHT INSPECTION)	08/01/22	31/12/22

The night route check of the co-pilot was valid till 24.05.2022. The last simulator training in respect of co-pilot was done in July 2019 as per the requirement of DGCA CAR Section 8, Series H Part II which requires recurrent training at least once in two years, on a FFS Level B/C/D or FTD 6/7 (FAA Designation). The minimum duration of this training is 8:00 hrs including 04 hours of Emergencies. In the wake of COVID-19 pandemic, DGCA had issued an operational circular 02 of 2020 dated 08 July 2020 which was further extended vide DGCA e-mail 08 Jan 2021 wherein relaxation/extension was given to the crew including helicopter pilots for recurrent training which required pilot (with Multi Engine rating) to do 04 hours (02h Critical Emergency Training and 02 hours IF Training) on aircraft with a TRE/TRI. The said training was valid for 01 year. Accordingly, the training for critical emergencies for co-pilot were carried out in July 2021 with another company pilot who was a TRE.

1.6 Aircraft Information

1.6.1 A109E General Description

The A109E is a high-speed, high-performance, multi-purpose helicopter powered by two Pratt & Whitney Canada PW206C or two Turbomeca Arrius 2K1 engines, with:

- Four-bladed, fully articulated main rotor
- Titanium/composite main rotor head with elastomeric bearings
- Two-bladed tail rotor
- Retractable tricycle-type landing gear.

The airframe consists of two major assemblies: the forward fuselage and the aft fuselage (tail boom).

The forward fuselage comprises the nose section, the cabin and the rear section. The nose section includes an upper compartment for the electric and electronic equipment, and a lower compartment which accommodates the hydraulic system accumulators the nose landing gear and other hydraulic components.

The cabin includes the crew compartment (cockpit) and the passenger compartment. A hinged door, on both sides of the cabin, permits direct access to the cockpit, and a large hinged door is located on both sides of the cabin for access to the passenger compartment. Seating is provided for the pilot (right side) and a passenger (or co-pilot) in the cockpit, and five or six passengers in the relevant compartment.

The rear section accommodates the fuel tanks, the main landing gear compartments, the baggage compartment and the electric and electronic equipment compartments. The upper deck, located above and aft of the cabin area, accommodates the hydraulic system reservoirs and filter groups, the main transmission and engine oil coolers and the relevant fans, and the engines. The upper deck is enclosed by removable fairings and cowlings. The tail boom is bolted to the forward fuselage and supports the tail rotor and the relevant drive system. The tail boom includes the elevators, the vertical fin, the tail skid and the tail cone.

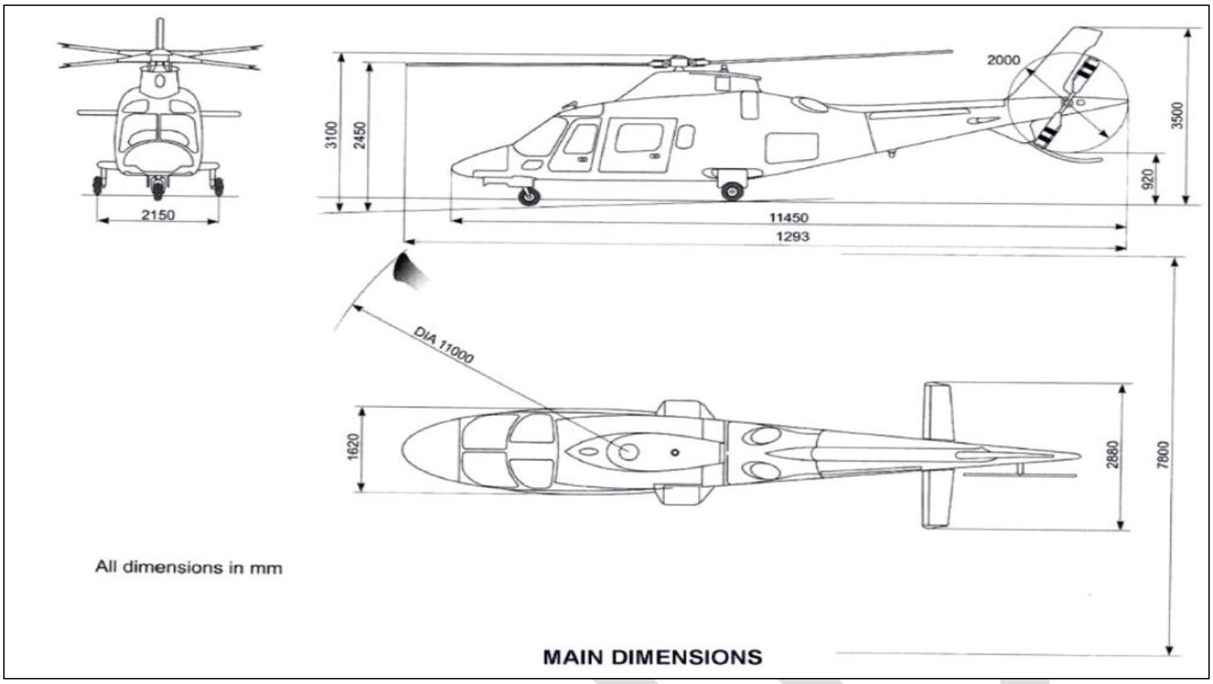

Fig 2: Agusta A109E Helicopter Dimensions (3 view)

A. FUSELAGE

The fuselage mainly consists of the following sub-systems:

- The forward fuselage.
- The tail boom.

<u>Forward Fuselage</u>

The forward fuselage comprises the nose, the pilot and passenger compartments and the part of structure from the passenger compartment to the tail boom. The cabin nose houses the nose landing gear, the battery and supports the instruments panel; the structure includes two longitudinal beams, two bulkheads, ribs, stringers, skin made from light alloy and transparent panels. The pilot and passenger compartments are made by a structure in light alloy and honeycomb panels with two main beams, frames, bulkheads, ribs, stringers, skin, transparents and windshield. The structure aft of the passenger cabin houses the main transmission, power plant, main landing gear and is made by two beams, frames, ribs, stringers, skin and is completed by a bulkhead where it is attached the aft section or tail boom by means of four bolts.

<u>Tail boom</u>

The tail boom is a basic semi-monocoque structure which is attached to the fuselage aft section by four bolts. The tail boom supports the elevator, the vertical fin, the tail skid, the 90o gearbox and the tail rotor as well as the tail rotor drive shaft.

<u>Tail skid</u>

The tail skid is attached by bolts to the tail boom lower end. It consists of a bent tube provided with a strut assembly, enclosed in a suitable fairing.

Vertical fin

The vertical fin is part of the tail boom structure. It is located on the upper surface of the tail boom.

Stabilizers

The helicopter is provided with an elevator secured to the tail boom. The elevator, comprises two elevator panels rigidly connected to the torque tube. Each elevator panel is provided with a tip cover which houses the navigation light. The torque tube is held in the tail boom structure by means of four half fittings (two on each side).

B. TAIL ROTOR ASSEMBLY (CONSTRUCTION AND OPERATION)

This section provides a description of the construction and operation of the tail rotor assembly and its rotating controls. The function of the assembly is to produce an aerodynamic force to counteract the torque reaction caused by the main rotor during flight.

The amount of aerodynamic force produced can be varied by changing the pitch of the blades (collective only) through the tail rotor flight control system and pitch change mechanism. This permits the pilot to select heading changes about the vertical (normal) axis of the helicopter.

Tail rotor is a semi-rigid two bladed teetering rotor, because the blades are free in the flapping plane but are restricted in the lead and lag planes. The various elements of the Tail Rotor are described in greater detail in the following paragraphs.

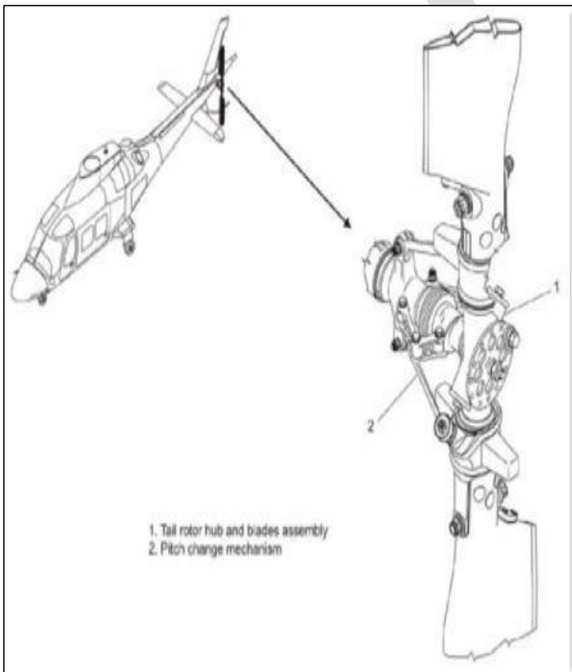

Fig 3: Tail Rotor installation

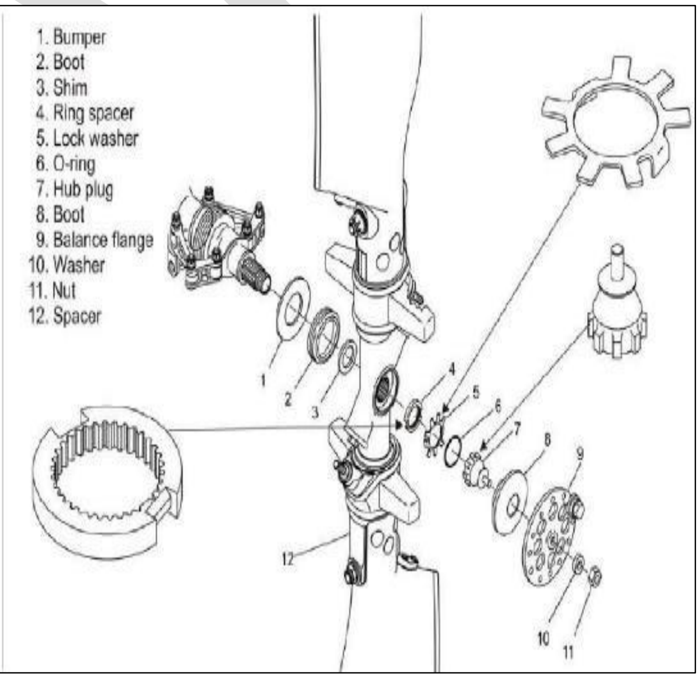

Fig 4: Tail Rotor installation components

Tail Rotor blades

Two tail rotor blades provide a lateral thrust component that acts to counteract the torque forces generated by the main rotor drive, or the thrust can be varied to provide directional control of the aircraft.

Tail Rotor Head – Hub assembly

The tail rotor is a semi-rigid teetering rotor that comprises the hub and the attaching parts between the blades and the hub. The hub is a one piece, forged, corrosion resistant steel unit, machined to its final form. Its basic form is an asymmetric cross between two pipes that intersect on the tail mast axis. The smaller arms of the hub form a teetering hinge with the trunnion pin, which is splined to the tail rotor shaft. This hinge allows to the rotor head to tilt so that the rotor blades, which are yoked to the longer arms of the hub, can flap. Each blade is linked with the hub by the retention strap assembly, and by a cylindrical elastomeric bush that connects the outer diameter of the longer arm of the hub and the inner diameter of the blade's root. This link allows the pitch change of the blades by feathering movement.

The teetering hinge is formed by two bushings that connect the tail rotor hub with the trunnion pin. Two covers are retained on the trunnion pin by two nuts. These covers prevent movement of the hub along the hinge axis and form the sealing element of the teetering hinge assembly. Friction between the covers, the trunnion pin and hub is reduced by the installation of dedicated frictionless washers.

The link between the tail rotor mast, the tail rotor hub and the blade assembly is formed by:

- the splined coupling between the tail rotor mast and the trunnion;
- the special hub plug that is a threaded device featuring double locking which retains the trunnion pin against a shoulder located on the tail rotor sleeve assembly.
- These interfaces are all sealed, to avoid external contamination. A balancing flange is fitted on a shoulder machined on the special hub plug. The flange is retained by nut.

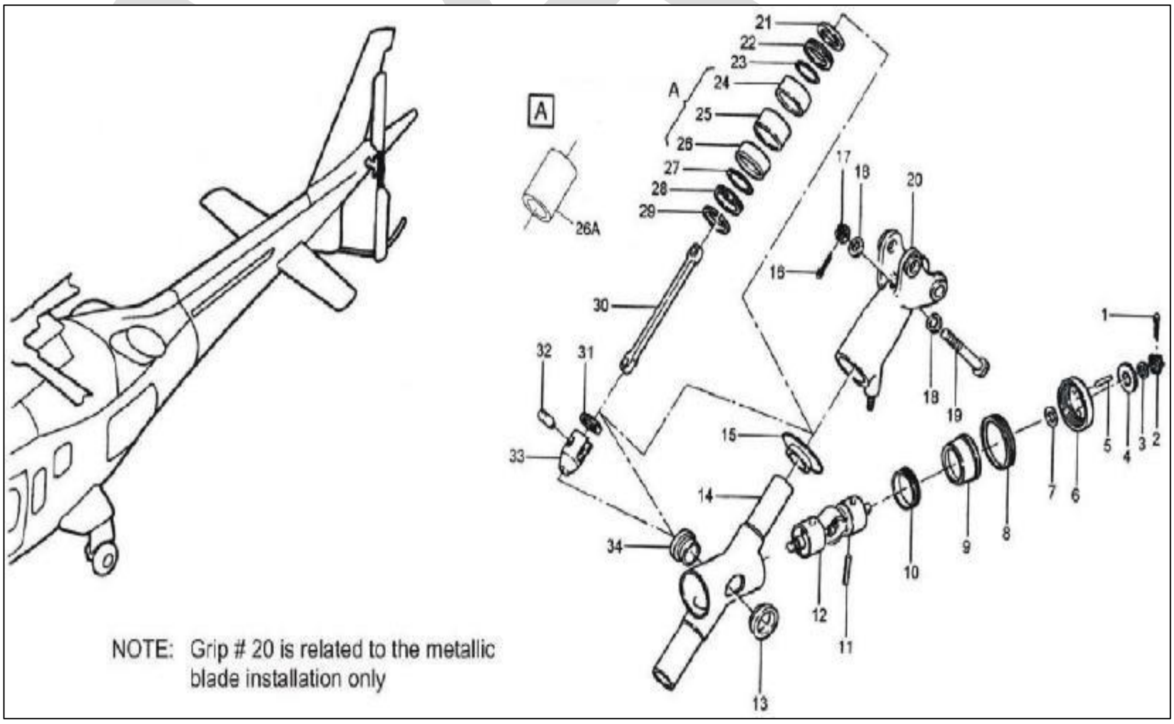

Fig. 5: Tail Rotor Hub components

Pitch Change Mechanism

This assembly transmits the pilot's control selections from the "fixed" airframe mounted Anti-Torque Flight Control System to the rotating tail rotor. The assembly consists of the following components.

- Torque Shaft

  A tubular shaft mounted vertically on the bearings in the rear lugs of the Tail Rotor Gearbox Case.

- Torque Shaft Levers

  Two levers are secured, by split clamp fittings, to the upper and Lower ends of the Shaft. The lower lever has a clevis extension which provides the attachment point for the control tube of the Anti-Torque Flight Control System.

- Control links

  Two fixed length links, with spherical self-aligning bearings in each end, which connect the levers with the Thrust Sleeve.

- Thrust Sleeve

  A cast alloy cylinder, shouldered and threaded internally, with two integral lugs. This Sleeve fits over the output shaft and, through the Torque Shaft and Levers, converts Flight Control inputs to axial movements along the axis of the shaft.

- Scissor Assembly

  Two links, hinged together at the center, with their ends secured to the lugs on the Thrust Sleeve and on the front face of the Gearbox Case. This Assembly prevents the Sleeve from rotating while permitting it to move axially.

- Thrust Bearing

  A twin row ball bearing set (Duplex), pre-lubricated and sealed with the outer races secured against a shoulder inside the Thrust Sleeve by a ring nut.

- Sleeve

  A steel sleeve is located on tail rotor gearbox output shaft and takes drive from it, through a series of splines. The sleeve rotates with output shaft and is maintained centered by means of a Teflon bushing bonded internally.

- Slider

  The slider is a casting with an integral crosshead on it and with two Teflon aluminium bushings installed internally to permit axial movement to the slider on steel sleeve. The rotational movement to the slider is given by a double scissor system connected between steel sleeve and slider.

- Pitch change links

  Two fixed length Links, with spherical self-aligning bearings in each end, which provide the connection between the Cross Head and the Pitch Change Horns on the Grips. Thus, axial movements of the Thrust Sleeve, Slider and Cross Head are converted to pitch changes on the Rotor Blades.

All these components are reported in the exploded view in Figure 6 & 7 below.

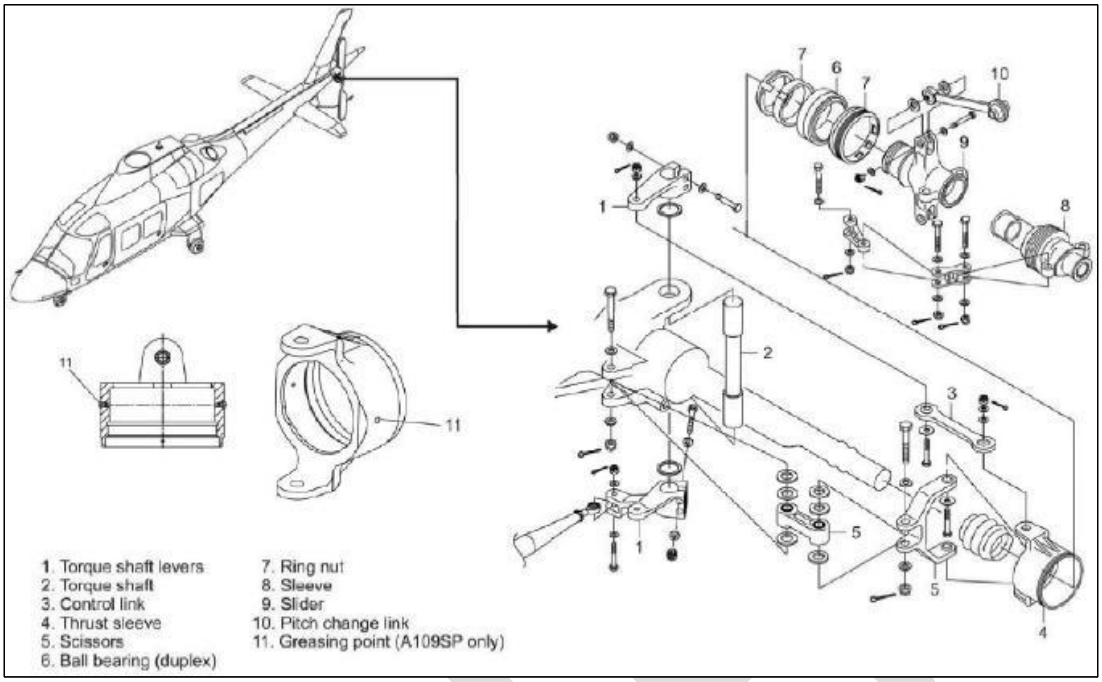

Fig. 6: Tail Rotor Pitch change mechanism

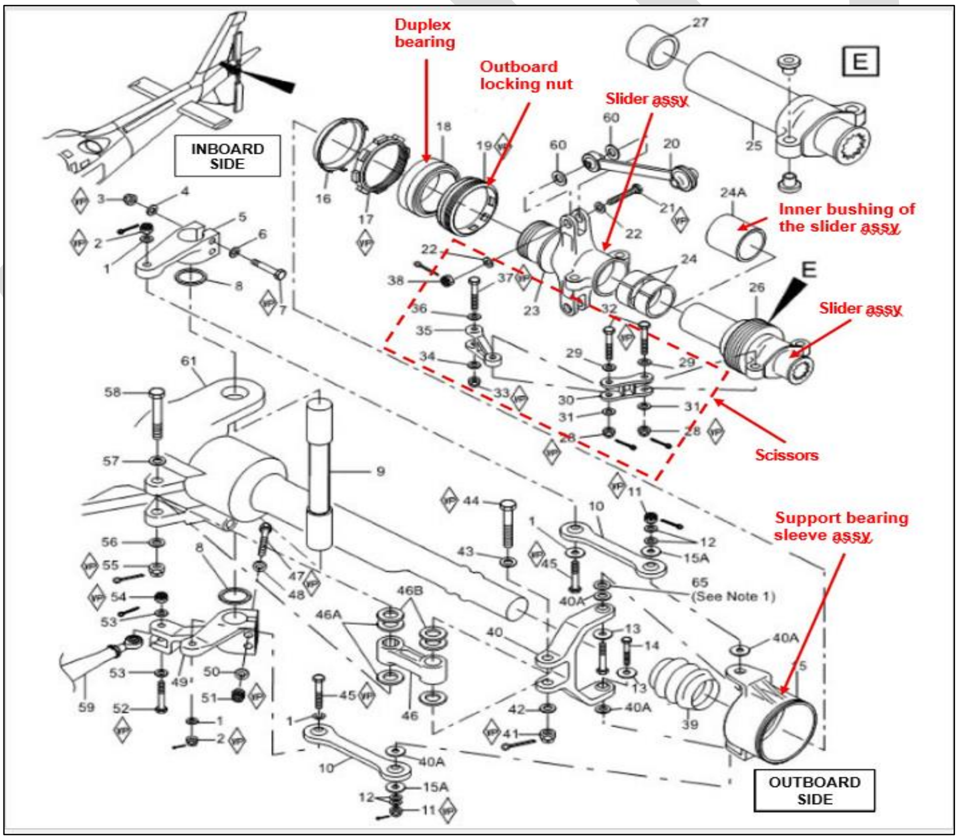

Fig 7: Tail rotor hub – Slider Assembly

<u>Tail Rotor Drive System</u>

The tail rotor drive system transmit power from a drive on the main transmission to the tail rotor through three drive shafts and the 90-degree gearbox. The 90-degree gearbox provides a 90° change in the direction of drive and a 2,8 to 1 speed reduction between the input shaft and the output shaft on which the tail rotor is mounted. The tail rotor drive system includes:

- The tail rotor drive shaft installation

- The 90-degree Gearbox
- The 90-degree Gearbox monitoring system.

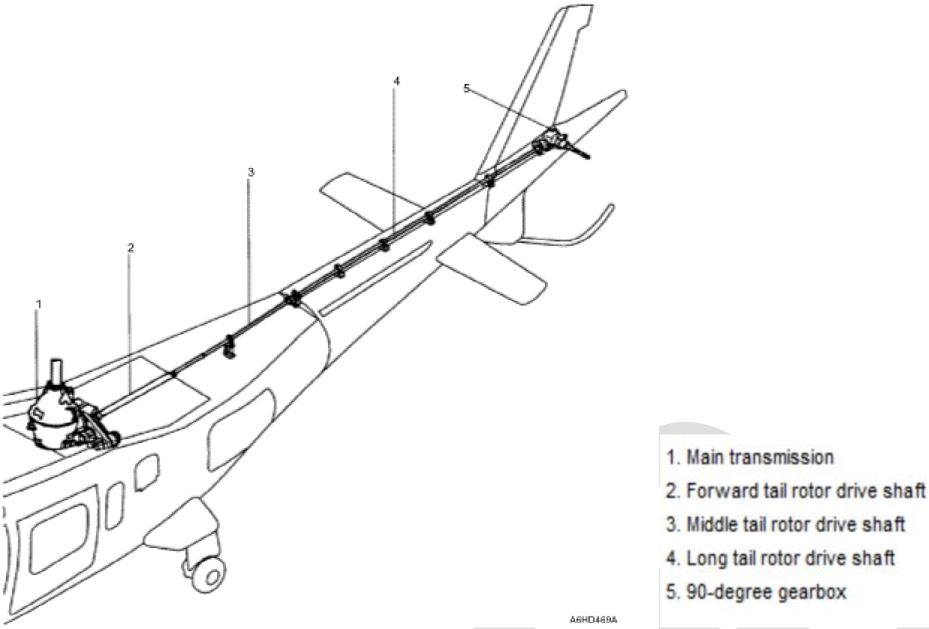

Fig 8: Tail rotor Drive System

<u>90 Degree Gearbox (Figure 9)</u>

The 90-degree gearbox consists mainly of mounting sleeve (5) case assembly (6), input pinion assembly (4) and cover and output shaft assembly (1). The 90-degree gearbox is attached to the structure through mounting sleeve (5). The case assembly is provided with a breaker type filter cap, oil level sight (3), magnetic chip detector (2), an oil drain plug, and mounting lugs for the tail rotor pitch change mechanism. The input pinion assembly is provided with a spiral level gear and the splines for the adapter of the tail rotor drive shaft. The input pinion is supported by a duplex ball bearing and a single row roller bearing.

The cover and output shaft assembly consists mainly of a cover, attached to the case assembly, and a flanged shaft, with a level ring gear bolted to the flange. The shaft is supported by a duplex ball bearing, mounted in the cover, and a single row roller bearing, mounted in the case. The shaft is provided with two sets of splines and a threaded end. The inboard set of splines provided drive and alignment for the pitch change mechanism.

The outboard splines and threads are used to drive and secure the tail rotor.

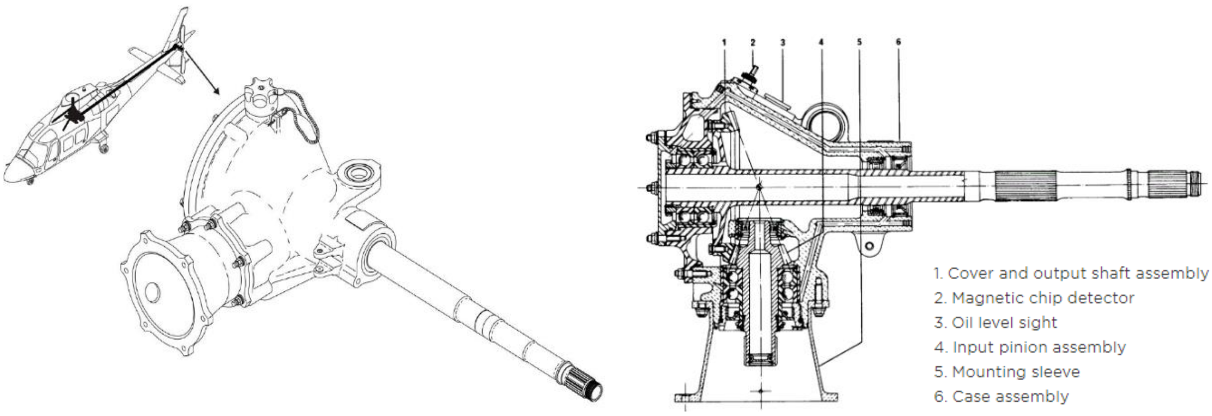

Fig 9: 90 – Degree Gearbox System

The helicopter details regarding Rotor Flight Control System including Wheel Brake System is provided in Appendix ‘A’ of this report.

1.6.2 Emergency Procedures as per A109E Rotor Flight Manual

Drive System Failures (Tail Rotor Failure)

As per the RFM of A109E helicopter, following emergency procedures are required to be followed by the crew in case of tail rotor failure.

NOTE

In case of NR/N2 switch locked at 102% the pilot can complete the flight provided that the airspeed is limited to 130 KIAS.

Correct trouble before next flight.

DRIVE SYSTEM FAILURES

TAIL ROTOR FAILURE

A tail rotor drive failure results in a loss of yaw control with a consequent yaw to the right, which is the more rapid, the less the forward speed is and the more the torque level is.
In fact the vertical fin produces an antitorque component which is a function of the forward speed and which permits to control the helicopter in low torque conditions.
A tail rotor drive failure may be accompanied by noise, vibration or oscillation in the tail section.
The action to be taken is different whether the helicopter is in hover or in forward flight.
In both cases the landing should be made at the lowest possible power or even with both engines out.
While a tail rotor drive failure in hovering is immediately detected, the same failure may be less evident in cruise.
In case of an event making suspect of a possible trouble in the tail section when flying at cruise speed, proceed as follows:

Altitude	: Maintain the cruise altitude.
Airspeed and pedal control	: Reduce gradually to 60 KIAS and meanwhile check the helicopter response to pedal control displacement and the appearence of any anomalous vibrations and/or noise.

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If the check confirms the tail rotor failure, proceed as per the paragraph "COMPLETE LOSS OF TAIL ROTOR IN CRUISE", otherwise carry out the following further check:

Airspeed	: Maintain 60 KIAS.
Collective	: Slowly raise, to increase the antitorque demand, as close as possible to maximum continuous power and let the helicopter climb.
Pedal control	: Check the pedal effectiveness to control the yaw and any anomalous vibration and/or noise.

If the pedal effectiveness does not result sufficient to control the yaw, proceed as per the paragraph "COMPLETE LOSS OF TAIL ROTOR IN CRUISE".
If on the contrary nothing seems to confirm a tail rotor failure, continue flight.

COMPLETE LOSS OF TAIL ROTOR CONTROL IN HOVERING

PROCEDURE

Collective	: Lower as necessary to reduce yaw rate and to land.

If height above ground permits:

Engine power levers	: Slam to OFF.

NOTE

Operate engine power levers for a quick reaction either in AUTO mode or in MANUAL mode.

Collective	: As necessary to cushion the touchdown.

NOTE

A slight rotation can be expected on touchdown.

COMPLETE LOSS OF TAIL ROTOR IN CRUISE

PROCEDURE

Collective	: Lower as necessary to eliminate yaw to the right.
Airspeed/power	: As necessary in order to reach a suitable landing site.

NOTE

Increased power will allow an extension of the flight path, however an increase in power necessitates an increase in speed to prevent the helicopter from turning.

Landing gear lever	: DOWN.
Nose wheel lock	: ON.
Parking brake	: OFF.

On reaching the point of intended landing:

Collective and cyclic	: As needed to control lateral-directional stability, touch down point, speed and attitude.

If the above procedure is not suitable to the landing site:

ENG MODE switches	: OFF (full counterclockwise)

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1.6.3 VT-CHG Specific Information

Helicopter Model	AGUSTA A109 E
Helicopter S. No.	11712
Year of Manufacturer	2007
Name of Owner	Directorate of Aviation, Govt. of Chhattisgarh
C of R	Certificate No.: 3670, Cat.: ‘A’, Issued on 13-12-2007
C of A	Certificate No.: 3079, Cat.: Normal, Issued on :19-12-2007
Category	Cat.: Normal, Sub- Division: Passenger.
C of A Validity	Lifetime validity subject to validity of ARC

A R C issued on	25-02-2022
ARC valid up to	24-02-2023
Helicopter Empty Weight	2044.92 Kg
Maximum Take-off weight	3000 Kg
Date of Helicopter weighment	05-09-2017
Max Usable Fuel	660 Kg
Max Payload with full fuel	125.08 Kg
Empty Weight C. G	3.467 meter aft of the datum
Next Weighing due on	05-09-2022
Total Helicopter Hours	3343:55 hours as on 11.05.2022.
Last major inspection	3200:00 hours Schedule Inspection at 3159:10 Airframe Hours on 06 May 2021
Engine Type	PWC 206C
Engine Sl. No.	L.H No.:01 – PCE-BC0669 R.H No.:02 – PCE-BC1007
Last major inspection	3200:00 Schedule Inspection at 3159:10 Airframe Hours on 06 May 2021 at Engine Hrs.: - L.H No.:01 – PCE-BC0669 Hrs.: 3052:10 R.H No.:02 – PCE-BC1007 Hrs.:202:05
Repairs / Replacement carried out after last major inspection till date of accident	1. Replacement of EAPS (Engine Air Particle Separator) Pressure Switch No.2 P/N: 109-0840-16-101 on 28-05-2021 at 3167:30 Airframe Hours. 2. Replacement of Airframe fuel filter element P/N: KD651510 on 30-05-2021, 3167:30 Airframe Hours. 3. Replacement of Cabin Step Linear Actuator, P/N: 209-062-214-101 on 31-05-2021 at 3169:40 Airframe Hours. 4. Replacement of Transmission Oil Pressure Switch P/N: 109-0729- 24-121 Date: 12-07-2021 at 3186:35Airframe Hours. 5. Replacement of R.H Side Engine Fire Extinguisher P/N: 27300-1 on 20-07-2021 at 3186:35 Airframe Hours. 6. Replacement of Digital chronometer Battery P/N: 2/3 “AA” on 03-08-2021 at 3191:45 Airframe Hours.

	7. Replacement of Non-rotating scissors lever P/N: 109-0110-54-111 & 109-0110-60-1on 31-08-2021 at 3208:30 Airframe Hours. 8. Replacement of Tail Rotor Bumper P/N: 109-0133-19-101 on 01- 10-2021 at 3222:45 Airframe Hours. 9. Replacement of Swash Plate Support P/N: 109-0110-05-101 on 28-10-2021 at 3231:30 Airframe Hours. 10. Replacement of Main Rotor Servo Actuator (Red) P/N: 109-0110- 42-124 on 28-10-2021 at 3231:30 Airframe Hours. 11. Replacement of Valve, Pressure reducing and Shut off (Environment Control system) P/N: 4173B000-002 on 13-12-2021 at 3275:15 Airframe Hours. 12. ECS (Environment Control System) Trouble Shooting on 14-12-2021 at 3275:15 Airframe Hours. 13. Replacement of Landing gear retraction system Hose Assembly, Non-metallic P/N: A380AB2B00B0250Y on 08-01-2022 at 3286:25 Airframe Hours. 14. Replacement of Landing gear retraction system Tee reducer fitting P/N: AS1031-040404 on 08-01-2022 at 3286:25 Airframe Hours. 15. Replacement of R.H Side Engine Oil Cooling Fan Belt Toothed P/N: 109-0455-09-103 on 24-01-2022 at 3291:35 Airframe Hours. 16. Replacement of EDU No.2 P/N: 109-0900-42-2A08 on 10-02-2022 at 3297:40 Airframe Hours. 17. Replacement of Sleeve Rotating Swashplate P/N: 109-0110-69-105 on 11-03-2022 3303:40 Airframe Hours. 18. Replacement of Passenger Step Actuator Electro-Mechanical Linear P/N: 209-062-214-101 on 12-03-2022 at 3303:40 Airframe Hours. 19. Replacement of Engine Air Particles Separator (EAPS) Switch Pressure P/N: 109-0840-16- 101 on 22-03-2022 at 3311:35 Airframe Hours.
Total Engine Hours Since New	L.H No.:01 – PCE-BC0669: 3236:55 hours.

	R.H No.:02 – PCE-BC1007: 386:50 hours.
Total Engine Hours Since Overhaul	N/A
Aero mobile License	A-035/001/WRLO-08 Issued on :26-12-2019 Valid till: 31-12-2024

The load & trim was prepared for the first flight of the day and the CG was found within limits.

1.6.4 Aircraft Maintenance

1.6.4.1 Scheduled & Unscheduled Maintenance Program

As per Maintenance Planning Manual (MPM). The scheduled inspections consist of

- basic 50 hours/30 days inspection
- 200 hours inspection
- 400 hours inspection
- 800 hours inspection
- 3200 hours inspection and
- 12 months inspection

Apart from above scheduled maintenance there are other unscheduled special maintenance inspections needs to be carried out. Some of the relevant tasks are appended as follows: -

- Prior to the first flight of the day
- Between 5 and 10 hours of flight when aircraft is new or after reinstallation of the following components:
  - Main Rotor
  - Main Transmission
  - Tail Boom
  - Tail Rotor (90°) Gearbox
  - Engine Exhaust Ejector
  - Vibration Absorbers
- Each 25 Hours
- Each 100 hours
- Each 1600 hours, etc.

The MPM also includes following inspections: -

- **Uscheduled Maintenace Tasks (Conditional Inspections)** to be performed in accordance with 05-50-2 Conditional Inspections.
- **Optional Equipment** inspection tasks to be performed in accordance with 05-60 Optional equipments section.
- **Servicing Interval Tasks** to be performed in accordance with 05-70 Servicing.

The 200 hours and 400 hours scheduled maintenance inspections requires removal of tail rotor assembly from helicopter to carry out the specific task. The 50 hours/30 days inspection requires visual inspection of tail rotor assembly.

1.6.4.2 Last inspection and last major inspection schedule maintenance carried out on VT-CHG

- The last scheduled maintenance carried out on the aircraft was 50 hours/30 days inspection on 01.05.2022 at 3331 A/F hours, i.e., 12 Flying hours before the accident. During the inspection following task is required to be carried out on tail rotor as per section 05-30-1 of MPM: -

AREA N° 4 (FINS, 90° GEARBOX, TAIL ROTOR AND TAIL SKID)

1. Exterior for cracks, dents, missing and/or loose rivets and screws.
2. Tail rotor hub and blades for condition, contamination of oil/grease, security and freedom of flapping. Flap stop bumpers and boots for condition and damage. Tail rotor hub for unusual play along flap axis. Tail rotor blades for condition, scratches and dents.
3. Tail rotor pitch change mechanism for condition, security and unusual play.

It was observed that on number of occasions the 50 Hrs/30 days scheduled inspections were not carried out as per schedule and there have been delay in carrying out the same.

- Last 100 hrs unscheduled special inspection was carried out on 14.12.2021 at 3272 flying hours, i.e., 68 flying hours before the accident. Following task is required to be carried out on tail rotor.

10. EACH 100 HOURS

a. TAIL ROTOR

1) Check tail rotor for correct dynamic balance. Ref. to Para 64-00-9 for tail rotor hub and blade P/N 109-8131-02 or to Para 64A-00-8 for tail rotor hub and blade P/N 109-0162-01 or 109-0162-02.

- The last scheduled inspection of 200 hours on the helicopter was carried out on 31.08.2021 at 3209 A/F hours, i.e., 134 flying hours before the accident. Following task is required to be carried out on tail rotor as per section 05-30-2 of MPM: -

9. TAIL ROTOR

a. Tail rotor blades for voids. Ref. to Para 64-11-9 or 64A-11-8.

b. Pitch change mechanism bolts, connecting levers, scissors for wear and excessive play.

c. Bolts AN174-14 that connect the two links and the pitch control lever to the housing of the tail rotor pitch change mechanism for damage. Refer to Para 64-31-9.

d. (Only for tail rotor hub and blade assy P/N 109-0162-02-101).

1) Elastomeric bushings in the blades for condition, fretting and wear including relative hub contact area. Ref. to Para 64A-11-8.

2) Blades retention bolt for condition, corrosion and nicks. Ref. to Para 64A-11-8.

3) Bushings on flapping axis for wear and local debonding of teflon lining. Ref. to Para 64A-21-9.

e. (Only for tail rotor hub and blade assy P/N 109-8131-02-157).

1) Remove grip assy and inspect internal bushings liners and relative hub contact area for condition, fretting and wear. Ref. to Para 64-21-9.

2) Blades retention bolt shank for condition, corrosion and nicks. Ref. to Para 64-21-9.

3) Bushings on flapping axis for wear and local debonding of teflon lining. Ref. to Para 64-21-9.

f. Tail rotor hub trunnion covers for cracks (visual inspection, removal not necessary).

- The last scheduled major inspection carried out on the helicopter was 400 hours inspection wherein tail rotor assembly is required to be removed. The task also requires disassembly and reassembly of the Tail Rotor Pitch Change Mechanism which includes the Tail Rotor Housing and Slider Group. The task was carried out on 20.10.2020 at 3024:05 A/F hours, i.e., 319 flying hours before the accident. Following task is required to be carried out on tail rotor as per section 05-30-3 of MPM: -

8. TAIL ROTOR

a. Pitch change mechanism for corrosion, wear and debonding. Ref. to Para 64-31-8.

b. Bolt P/N 109-8131-09-1 or P/N 709-0160-47-101 and pin P/N 109-8131-08-1 of retention strap for condition, corrosion and wear. Ref. to Para 64-21-9.

c. Trunnion and its covers for condition and wear. Ref. to Para 64-21-9 or 64A-21-9.

1.6.4.3 Maintenance Documents (VT-CHG)

The investigation team perused the various maintenance documents pertaining to the helicopter VT-CHG submitted by the operator. Following are some salient observations: -

➢ Technical Logbook

- In the column for next inspection due for maintenance entry is required to be made for next inspection due, however, it was observed that for a period of about three months it was mentioned as 25 hrs special inspection rather than mentioning the actual scheduled/unscheduled maintenance due next.
- Whenever a component was replaced, in techlog sheet, only component name is being mentioned and not its part number.
- In the column of pilot acceptance, only signature of Pilot accepting the aircraft is appended without mentioning the license number. Most of the techlog pages removed after pilot acceptance (as per the company procedure) did not have pilots name.

➢ CRS

- Scrutiny of the CRS booklet was carried out and it was observed that CRS for some of the maintenance inspections including that of SB compliance carried out were not available in the booklet.

➢ Work Package

- Scrutiny of work package of various scheduled maintenance provided to the investigation team revealed that the CRS for most of the maintenance task was not available in records. In some of the schedule no entry was made for special tools used during the maintenance task.

➢ Log cards

- There were lot of cuttings observed in the entries made in the log cards.
- After an overhaul of a component, in most of the entries made under time since overhaul it is mentioned as ‘NEW’ rather than 00:00 hrs.
- The log card in respect of tail rotor hub assembly does not contain details of its various components. The tail rotor hub was replaced and it was installed on 01 Feb 2021.

➢ Log book

- It has been observed that there have been lot of cuttings and correction made on entries made in the aircraft log book.

1.7 Meteorological Information

The helicopter took-off from Raipur (VARP) and returned to Raipur from 20 Nm outbound. The IMD issues half hourly METARs. Relevant METAR reports at Raipur during the time of accident are given below:

Met Report at VARP	At 1430Z	At 1500Z	At 1530Z	At 1600Z
Wind	170°/04KT	190°/04KT	180°/04KT	150°/06KT
Visibility	6000 meters	5000 meters	5000 meters	5000 meters
Wx	-	HZ	HZ	HZ
Cloud	FEW 10000 FT	FEW 10000 FT	FEW 10000 FT	FEW 10000 FT
Temperature	36°C	36°C	36°C	35°C
Dew Point	20°C	20°C	20°C	20°C
QNH	1001	1001	1001	1001
Trend	NOSIG	NOSIG	NOSIG	NOSIG

1.8 Aids to Navigation

The helicopter was equipped with VHF, VOR, DME, ILS, ATC transponder, Radio altimeter, weather radar and GPS.

1.9 Communications

The helicopter was always in two-way communication with the Raipur tower on frequency 124.75 MHz. The intra cockpit conversation has also not indicated any problems faced by the flight crew in communicating with the tower during the flight.

The ATC tape recording of communication between VT-CHG and Raipur Tower was obtained. Some of the salient transcript of communication between the helicopter and Raipur Tower on frequency 124.75 MHz is given below: -

TIME (UTC)	UNIT	TRANSCRIPT
15:05:04	TOWER	Victor Tango Charlie Hotel Golf tower report distance
	VTCHG	Sir we are now Two Zero Miles and we have we are returning back sir due technical we would like to come and land back.
15:07:09	TOWER	Victor Hotel Golf tower report distance confirm all ops normal
	VTCHG	One Six DME sir operation normal we want to priority landing we would be like to make an overshoot then make a landing
	TOWER	Victor Hotel Golf tower roger approved report five miles Romeo Romeo Papa

	VTCHG	Five miles Romeo Romeo Papa and how many aircraft there for departure sir
	TOWER	No departure sir you are number one no delay
	VTCHG	Roger sir
15:08:05	TOWER	Victor Hotel Golf tower request vacation via Charlie or via state link
	VTCHG	Sir we might have a problem of vacation that is why we are asking to we might block the runway could you inform state captain …… to initiate a towing up.
	TOWER	Roger
15:15:21	VTCHG	Raipur Victor Hotel Golf we have air field in sight and we are making a low pass adjusting our speed for landing
	TOWER	Roger approved
15:16:16	TOWER	Victor Hotel Golf Tower Insight
	VTCHG	Roger
15:17:30	TOWER	Victor Hotel Golf Tower in sight runway 24 cleared to land wind 200 Degree, 04 Knots
	VTCHG	Two Zero Zero Four Hotel Golf
15:20:44	VTCHG	Raipur Victor Hotel Golf we are totally comfortable we will be making an approach landing on this
	TOWER	Roger approved if able vacated via Charlie
	VTCHG	Roger
15:21:13	VTCHG	We will go around sir and allow the aircraft to take-off and then we will land beginning of runway
	TOWER	Roger
	TOWER	Victor Tango Charlie Hotel Golf confirm all ops normal
	VTCHG	Operations normal sir and we have little rudder problem so you can make both the aircraft take-off then we will land in case there is hold up on runway
	TOWER	Roger
15:22:51	TOWER	Victor Hotel Golf tower in sight make a orbit at left downwind runway 24
	VTCHG	We will making loose flight sir we have less rudder control
15:23:29	TOWER	Victor Hotel Golf tower report endurance
15:23:36	VTCHG	We have one hour endurance
	TOWER	Roger
15:27:14	TOWER	Victor Tango Charlie Hotel Golf tower for information one aircraft is ready for taxi and another will get ready by another 20-25 Minutes
15:27:27	VTCHG	After one which is ready to taxi, we will land
15:33:27	VTCHG	Raipur Victor Hotel Golf visual with aircraft taking off positioning ourself for finals
	TOWER	Victor Hotel Golf roger report final runway Two Four

	VTCHG	Wilco Victor Hotel Golf
15:35:35	VTCHG	Hotel Golf is finals for two four
	TOWER	Victor Hotel Golf runway two four cleared to land wind one seven zero degree zero five knot
	VTCHG	One seven zero zero five Hotel Golf
15:36:51	VTCHG	Hotel Golf is going around
	TOWER	Victor Hotel Golf roger report left downwind runway two four
	VTCHG	Left downwind two four Hotel Golf
15:37:22	TOWER	Victor Hotel Golf and report intention
	VTCHG	Will make an attempt to land on this approach now
	TOWER	Roger report final runway two four
	VTCHG	Finals for two four Hotel Golf
15:39:06	VTCHG	Hotel Golf is on finals
	TOWER	Victor Hotel Golf runway two four cleared to land wind one six zero degree zero five knots
	VTCHG	One six zero zero five Hotel Golf
15:40:30	IG02521	Raipur Raipur this is i fly two five two one
15:40:45	IG02521	Raipur i fly two five two one
	TOWER	I fly two five two one Raipur tower
	IG02521	Jai hind to you sir we are a total of…
15:41:05	IG02521	Raipur i fly two five two one
	TOWER	I fly two five two one Raipur tower
	IG02521	Confirm all ops normal
	TOWER	Crash landing helicopter
	IG02521	Roger ok we main we are ready sir please advise maintaining silence for the time being

1.10 Aerodrome Information

Raipur Aerodrome named as Swami Vivekananda Airport is in the state of Chhattisgarh. It is maintained by Airports Authority of India (AAI). Its ICAO nomenclature is VERP. Following are the basic information about the aerodrome as on date of accident: -

a)	Aerodrome Name	Swami Vivekananda Airport, Raipur (VERP)
b)	Aerodrome Reference Code	4C
c)	Aerodrome Location	135° /18KM from Raipur Railway Station
d)	Aerodrome Reference Point (WGS-84)	21°10’52’’ N; 081°44’19’’ E
e)	ARP Elevation	1027 ft
f)	Aerodrome Elevation	1041 ft

g)	Elevation of Runway Threshold	RWY 24 - 1034 ft; RWY 06 - 1016 ft
h)	Aerodrome Reference Temperature	42°C (May)

Runway declared distances

RWY Designation	TORA (M)	TODA (M)	ASDA (M)	LDA (M)	Remarks
06	2286	2286	2286	2156	Threshold RWY 06 displaced by 130 m.
24	2286	2286	2286	2286	

Visual Aids & Markings (Runway)

Runway 24	SALS-420m (under Notam due RWY Extn work), Threshold lights (Green), HIRL, End lights (Red).
Runway 06	SALS-NIL, Threshold lights (Green), HIRL, End lights(Red).
RWY Markings	RWY Designator, Threshold Marking, Aiming Point, Center Line, Touchdown zone markings, RWY Side Strip marking, Turnpad markings.
Other Visual markings	Signages – RWY06/24, Taxiway A, B, C & D and VOR Check Point marking, RWY Exit Sign Markings – Taxiway A, B, C & D

Rescue and Fire Fighting

AD category for fire fighting	CAT-6 (CAT-7 on demand)
Rescue equipment	AVBL as per category
Capability for removal of disabled aircraft	As per disabled Aircraft Removal plan (VERP/FS/2019/DARP)
Remarks	NIL

The operator i.e., Government of Chhattisgarh is having a hangar inside the aerodrome premises. The helicopter was taxied to the dispersal of state hangar after the first flight of the day and was subsequently taxied from the dispersal for the check flight which met with the accident.

All equipment available at the aerodrome were reported to be serviceable on the day of accident.

1.11 Flight Recorders

The helicopter was equipped with FA2300 MADRAS CVDR unit by L3 Communications with Part No. 2316-1600-00 & Serial No. 001070596. The unit was retrieved from the helicopter wreckage. There was no visual damage to the unit as seen from outside. However, as the helicopter was subjected to heavy impact with ground during the accident there was possibility of internal damage as there were some loose parts inside the recorder which was observed to be moving.

Since the unit was suspected to have sustained internal damage, it was opined to get the data recovery from the approved lab facility capable of recovering data from damaged units so as to ensure that no data is lost. Assistance of ANSV, Italy (State of Manufacturer of Aircraft) was taken and data download was carried out at ANSV's Flight Recorders Lab in Italy.

FDR readouts were analyzed and copy of the readout was also provided to OEM i.e., Leonardo Helicopters (LH) for their analysis of the events. The reports have been used to analyze and corroborate the circumstances leading to the accident.

1.11.1 Cockpit Voice Recorder

The CVR Recordings from all four channels were retrieved. Duration of recording was of 02:04:27 Hrs. The conversation between cockpit crew were in Hindi and English but mostly in Hindi. The conversations in Hindi were translated to English for better understanding. Salient transcript of the CVR recording pertaining to the accident flight is given below: -

CVR Reference time	From	Transcript
01:13:47		Helicopter took-off after clearance from ATC
01:23:32 - 01:24:00	Co-pilot	The co-pilot (PF) identified some rudder issue and called out "there is some reduction in rudder effectiveness" PIC also confirmed the same.
01:24:40	PIC	Crew discussing regarding landing back and the PIC is now PF. (No call out for handing/taking over controls)
01:25:12	PIC	PIC tells co-pilot that the rudder is coming in between
01:25:53 - 01:26:15	PIC	PIC tells co-pilot that they have to check the effectiveness and further said that the rest of the parameters are normal.
01:26:20	PIC	PIC tells co-pilot that rudder is working little bit and it is not fully out.
01:26:36	Co-pilot	Co-pilot says upto 50 knots they are able to manage, however, the PIC replies that they need to check during descent as this was checked in level.
01:27:07		Crew discussing that upto 40 knots the aircraft is holding, hence, they will go back and land at 40 knots.
01:27:40	PIC	PIC tells co-pilot that let the aircraft (on ground) go after that they will try to land. PIC further tells co-pilot that they need to declare because without towing arm they will not be able to vacate and the runway will be blocked.
01:28:18	PIC	PIC asks co-pilot to call someone and ask for towing arm.
01:28:45	Co-pilot	Co-pilot probably tries to call but says there is no Network.

01:28:48	ATC	Co-pilot Conversation with ATC…. regarding landing back….
01:29:21		PIC and co-pilot discussing that First they will carry out an overshoot (low pass) along the runway to check speed and then they will land.
01:29:35	Co-pilot	Co-pilot asks PIC if there is Effectiveness upto 60 knots…for which PIC tells No, now it is fully gone, but it is there for right rudder.
01:30:38		Crew discussing that right rudder is coming in between but left is not coming.
01:30:54	ATC	ATC confirming if all operations are normal and subsequently clearing the helicopter for low pass…
01:31:20	PIC	PIC tells co-pilot that there may be a problem (vacating the runway) and they need to declare. The same was acknowledge by the co-pilot.
01:31:40	PIC	PIC tells co-pilot that we have to declare but let us confirm the emergency first.
01:31:50		ATC confirming with crew regarding from where they will be vacating the runway. The co-pilot informs ATC about problem in vacating…and requested to inform chief pilot for towing arm.
01:32:25	Co-pilot	Co-pilot asks PIC if rest of the parameters are normal?
01:33:02	PIC	PIC says that rest of the parameters are normal and said they need left rudder which is not coming. Further, PIC tells co-pilot that the Right rudder is coming upto certain extent thereafter it is not coming and it is stuck at one place.
01:33:05 - 01:33:55	PIC	PIC tells co-pilot that they need to refer the checklist.
		PIC further tells co-pilot that they have checked all and there are no findings. PIC further said they will do lower speed checks along with runway to know which direction the helicopter is maintaining.
	Co-pilot	Co-pilot further reads the checklist
	PIC	PIC responds that there is no total loss as there is no sound from the tail rotor and there is no violent rotation with reduction in speed.
	Co-pilot	Co-pilot acknowledges the same.
01:34:29		ATC conversation
01:34:36	Co-pilot	Co-pilot asks PIC if anything, they need to tell ATC for which PIC says “No, runway block that is important”
01:35:11 - 01:35:45	Co-pilot	Co-pilot on mobile briefing Chief pilot about the situation (Slight Loss of tail rotor control) and requested for towing arm.
01:36:15	PIC	PIC asks co-pilot “Do you see any action left….”
01:37:25	ATC	…………………ATC interference ………………………
	Co-pilot	Crew going through the RFM emergency procedures for loss of tail rotor effectiveness; the co-pilot reading the procedures.

	PIC	PIC says “confirm no vibration….”
	Co-pilot	Co-pilot continues reading the RFM emergency procedures for loss of tail rotor effectiveness.
01:37:33	ATC	………………..ATC conversation ……………………….
01:38:59	PIC	Co-pilot informs PIC that “we are cleared for 24”
01:39:25	PIC	PIC calls out “Ok descending Sir….” and co-pilot acknowledges
01:41:15	ATC	ATC gives Landing clearance….
		ATC asking an aircraft on ground to stand by….
01:42:17	Co-pilot	Co-pilot calls out “We are on approach now….”
	PIC	PIC says “Ok I will keep the nose little bit to the left” and the co-pilot acknowledges.
01:42:27	PIC	PIC calls out “Ok….light ON..”
01:42:39	Co-pilot	Co-pilot calls out “…..430 sir….”
01:42:41	Co-pilot	“….410 ….”
01:42:47	Co-pilot	“Ground speed….now…. 69 knots, 68 knots, indicated 70.”
01:42:57		“We are 330 feet; 60 knots.”
01:43:05		“280 feet”
01:43:17		“250 feet, 60 knots”
01:43:25		“245 now sir”
01:43:33		“Ground speed 40 knots”
01:43:37		“38 knots…”
01:43:42	PIC	PIC calls out “OK…. it means we can land below 40….it has come to ground effect now”
	Co-pilot	Co-pilot confirms “Sir then it will hold”. PIC acknowledges “correct”
01:43:50		Auto call out of 150 feet.
01:44:25	PIC	PIC says “We will come close to the ground….or if you want we can land also”. The co-pilot responds that they will not be able to clear the runway and doubt if towing arm will be available by that time, however, tells PIC that they can go low.
01:44:27		Conversation with ATC; Co-pilot telling ATC that they will make an approach landing in this approach itself.
01:44:40	Co-pilot	Co-pilot tells PIC to Go around and allow the aircraft (on ground) to take-off and then land.
	PIC	PIC acknowledges and asks co-pilot to hurry up and inform ATC.
01:44:58		Co-pilot communicates to ATC that they will go around and allow that aircraft to take-off then they will land beginning of runway.
01:45:12	PIC	PIC tells co-pilot that they will not land at beginning and will do it midway in order to settle.
01:45:37 -	Co-pilot	Co-pilot asks PIC if the helicopter is now turning to the left.

01:46:02	PIC	PIC says it is turning but informs that rudder is ineffective and it is stuck at one place at 40-50 knots.
01:46:17	PIC	PIC tells co-pilot to let both the aircraft on ground to take-off.
01:46:21	ATC	ATC asks if all operations are normal. Co-Pilot responds that all operations are normal and informs that there is a little Rudder problem (as conveyed to co-pilot by PIC). Co-pilot further conveys to ATC that both the aircraft (on ground) can take-off first and then they will land in case if they hold up on runway.
01:46:37	ATC	ATC instruction “In sight make an orbit-left downwind.”
	Co-pilot	Co-pilot conveys to ATC “We will make loose flight sir we have less rudder control.”
		PIC then tells co-pilot that there is no problem in making orbit and explains that when the helicopter comes close to the ground (ground effect) that is when it has the tendency to go to the right. PIC asks co-pilot to keep reminding to maintain 40 knots. Co-pilot acknowledges the same.
	Co-pilot	Co-pilot asks PIC if they will not lower the collective?
01:47:12	PIC	PIC says “No we will lower it”
01:47:14	ATC	ATC asking for endurance. Co-pilot conveys that they have one hour endurance (as conveyed to co-pilot by PIC).
01:47:59 - 01:48:23	PIC	PIC tells co-pilot that all actions they have to take is complete and also the speed at which they are maintaining straight. PIC further conveys that they will be consuming little more fuel so that it becomes light and in the meantime the aircraft (on ground) can also take-off.
01:49:28 - 01:50:10	PIC	PIC again tells co-pilot that right rudder is coming but they need left rudder which is not coming.
01:50:41	PIC	PIC tells co-pilot that they will maintain 60 only and reduce towards the end to get the nose straight.
01:50:59 - 01:51:14		ATC informs “for info… one aircraft is ready for taxi and other….”. PIC asks co-pilot to convey “after the one which is ready for taxi they will land….” Co-pilot conveys the same to ATC.
01:52:07		Crew discussing about speed during landing
01:52:45	Co-pilot	Co-pilot asking PIC regarding landing techniques in such emergency condition.
	PIC	PIC conveys to co-pilot that they have to apply brakes and control the direction with the brake.
01:53:42 01:55:34		Co-pilot discussing with PIC about rudder. PIC tells co-pilot that they can taxi with the help of brake which they can decide after landing.

01:56:03	Co-pilot	Co-pilot discussing with PIC regarding use of collective.
	PIC	PIC says "No No, we will keep braking and keep reducing the collective."
01:56:55		Crew carries out landing Checklist….
01:57:11		Conversation with ATC
01:57:48	Co-pilot	Co-pilot confirms with PIC that with little higher speed the helicopter was controllable and PIC acknowledges the same.
01:58:35	Co-pilot	Co-pilot calls out "We are at 580 feet now…"
01:59:05	PIC	PIC tells co-pilot that It's good that there is no problem of power.
01:59:25	ATC	ATC gives landing clearance
01:59:30	Co-pilot	Co-pilot calls out "….200….57 knots."
01:59:48	Co-pilot	Auto callout of 150.
01:59:53	Co-pilot	Copilot calls out "100 feet."
02:00:23	Co-pilot	Copilot calls out "57 knots"
02:00:31	PIC	PIC tells Co-pilot "No…. tell them for go around again."
02:00:35	Co-pilot	Co-pilot conveys ATC for Go-around
02:00:43	PIC	PIC informs co-pilot that the speed got reduced slightly and asked co-pilot to just keep reminding not to reduce the speed.
02:01:09 - 02:01:15	ATC	ATC asking intention… PIC asks co-pilot to convey that they will try to land on this approach. Co-pilot conveyed the same to ATC ATC asked crew to report when on finals runway 24
02:01:55	Co-pilot	Crew carries out Checklist…
02:02:26	Co-pilot	Co-pilot calls out "OK Sir we are 80 knots 640 feet."
	PIC	PIC tells co-pilot that Indicated speed did not reach 80 and what you are calling out is the ground speed.
	Co-pilot	Co-pilot asks PIC if indicated speed is required for this and the PIC confirms the same.
02:02:51	Co-pilot	Co-pilot reporting position to ATC.
02:02:59	ATC	ATC gave landing clearance
02:03:03	Co-pilot	Co-pilot calls out "Ok Sir indicated 60, we are 350 feet"
	PIC	PIC calls out "Ok I am just giving the ROD now…."
	PIC	PIC calls out "Landing light ON…."
	Co-pilot	Co-pilot calls out "….60 knots…."
02:03:19		Auto callout of 150.
02:03:23	Co-pilot	Co-pilot calls out "Ok we are 60 Sir, 100 feet."
02:03:26		"….60"
02:03:34		"….60"
02:03:37		"….60"
02:03:39		"….60"
02:03:41		"….60"
02:03:43	PIC	PIC calls out "Apply brakes….apply brakes….apply brakes"

	Co-pilot	Co-pilot says “Sir?”
	PIC	PIC again calls out “Apply brakes….”
02:03:46	PIC	PIC instructs co-pilot “its ok its ok let it go…it will go to the right little bit.”
02:03:52	PIC	PIC calls out “No…No…No…don’t”
	Co-pilot	Co-pilot says “OK…”
02:03:56	PIC	PIC trying hard (probably trying to decelerate the aircraft and bring the nose straight)
02:04:01	Co-pilot	Co-pilot calls out “Ok collective….”
02:04:05	PIC	PIC says “oh shi…….”
02:04:07		Sound of helicopter started rotating along with sound of alarms in cockpit…. Subsequently, auto call out of “rolling ….rolling….” was heard in the cockpit.
02:04:16		Sound of Helicopter hitting ground…
02:04:27		Recording ends.

1.11.2 Digital Flight Data Recorder

The DFDR raw data was downloaded and converted in engineering parameters. The analysis of DFDR data was carried out with the help of ANSV, Italy & LH.

Following are the relevant observation in sequence from the time of take-off for the accident flight till the helicopter impacted the ground i.e., the time of accident. All the graphs and plots have been made using the CVDR internal timer as reference. Tentative Synchronisation with the UTC time has been done using CCTV footage, ATC tape time, but only for a few key points.

- The helicopter took-off at 14:57 UTC from Raipur.
- The flight was uneventful upto T= 697535s (15:05 UTC), where a slight alteration of the vibratory regime recorded by the CVDR tri-axial accelerometer (primarily on Ny and Nz). Its presence, coupled with the initiation of small periodic un-commanded attitude variation on the Pitch and Roll axis (max 2.5° pitch, 7° roll) may be considered an early indication of the impending malfunction of TR control. At this time the A/C was flying at 3540ft AMSL and 132KIAS.

- No Crew Alerting System (CAS) message was recorded in this phase.

- The Crew reacted to the emergency i.a.w the relevant RFM procedures: PIC controlled the A/C attitude changes with Cyclic inputs and the Tail Rotor Pedal authority was checked immediately, in order to properly identify the issue; TQ demand was managed with progressive and slow actions of the Collective, in order to both achieve a reduction in the need for anti-torque and maintain the current heading with only minimal cyclic inputs. The stabilising effect of the Tail Fin was enough to maintain the desired heading, even when IAS was also progressively reduced from 132 to 60-80kts.

Fig: 10. Flight Path Data for whole final flight.

- From the loss of Tail Rotor control onwards the Pedal recording shows a repetitive and progressive Left drift, reaching 100% over several minutes, before it was repetitively re-centered manually. As the Pedal position is recorded in the CVDR via a dedicated potentiometer installed on the control chain near below the Cockpit floor, this behaviour can be explained by the fact that, having lost the connection with the Tail Rotor rotating controls, there wasn't any significant load on the whole control chain beside the residual minimal friction within the connections between bell-cranks and rods. As from that point onwards the PIC was likely flying hands-on and acting on the Force Trim release switch (in order to maintain heading), the Magnetic Brake installed on the Pedal control chain was also de-energised, therefore the Pedals were in a condition of "neutral equilibrium" and thus their progressive drift may have been simply caused by small accelerations or variations in the A/C attitudes. This had of course no effect on the A/C controllability as the pedal was disconnected from the TR pitch controls.
- At T=698705s (approximately 15:26 UTC) the A/C data indicates a manoeuvre corresponding to a possible first landing attempt on RWY 24 at VERP, as the IAS was progressively reduced to 40 KIAS while the A/C was steadily descending down to a minimum barometric altitude of 1380ft AMSL with 240° magnetic Heading (magnetic declination at VERP is reported as 0.24° ± 0.30°, while the true heading of the RWY is 239°).
- The attempt was seemingly aborted as VT-CHG returned at 2000-2100ft AMSL while performing at least 4 full 360° orbits, all while the PIC maintained full control on the speed and attitudes.

- At T=699720s (approximately 15:43 UTC) a similar attempt as in case of T=698705s was made, which was also aborted. The same considerations on A/C positioning apply here.
- The A/C touched down on the 3rd attempt at T=699925s (15:46:57 UTC), where WOW become active with IAS = 52kts and magnetic Heading changing between 233° and 239°. The small RH yaw at touchdown is likely to be attributed to slight lack of antitorque control as the speed reduced below 60 KIAS.
  NOTE: the Altitude difference between the recorded barometric value at touchdown (1370ft) and the actual VERP RWY altitude (1040ft AMSL) can be explained by the QNH setting, which was 1001hPa according to the published METAR (corresponding to a delta of 336ft w.r.t 1013hPa)

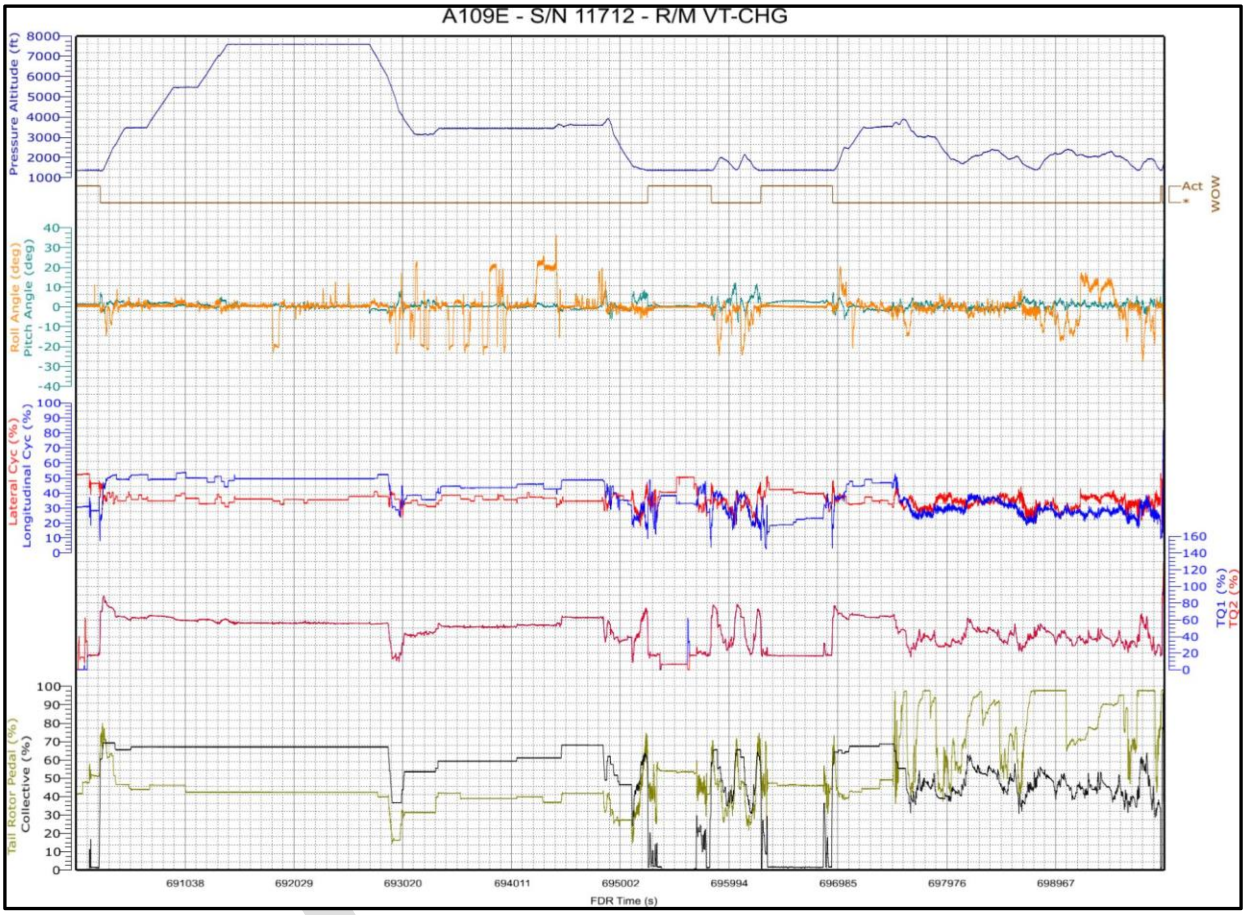

Fig: 11. Flight Control Data for whole final flight.

- For at least 13s the A/C rolled down RWY 24, with the PIC applying almost full AFT Longitudinal Cyclic (10%) and keeping the Lateral stick neutral (except for a short LH correction ~8s into the landing). Collective had been moved to MPOG and consequently TQ demand was minimal (18%), while both Engines were kept in FLT mode.
- Contemporarily the IAS trend showed a slow deceleration (from 52kts at WOW=ON down to 38kts 12s later) and a minimal RH yaw (8° in 13s, up to 247° magnetic).
- At T=699937s (15:47:00 UTC) an abrupt Collective pull was recorded (from MPOG to 68.7% in less than 2s), while the PARK BRAKE ON caution also activated.
- Both Engines immediately responded reaching 90-92% TQ, and the A/C initiated a sharp RH turn and lifted off again 1s later.

- From this point in time onwards the Flight Path data show a behavior consistent with a complete lack of control of the A/C, with at least 7-8 full 360° RH rotations with a yaw rate reaching above 360deg/s. VT-CHG climbed up to 1680ft AMSL before descending again while spinning CW, which is consistent with the footage of the Raipur Tower CCTV footage, up to the final impact at T=699959s (15:47:21 UTC).
- All of the CAS messages recorded during the LOC are considered as caused either by the extreme attitudes & rates (XMSN OIL PRES, 1-2 FUEL LOW) or by the large and uncoordinated control inputs (SERVO 1-2, ROTOR LOW, 2 PLA POS) during the spinning phase
- The only other CAS message active during the rolling landing and prior to the LOC was EMER UTIL CHRG, driven by the opening of the charge solenoid valve for the Emergency Hydraulic accumulator, which is an automatic process designed to refill such reservoir when on Ground (WOW=Active), its level is below a pre-set threshold and Pump pressure is available. Its activation does not impact in any way the operation of the Landing Gears, Toe and Park/Emergency brakes. As no other Utility Hydraulic family caution was active (e.g. MAIN UTIL PRES, EMER UTIL PRES) and pressures in the 2 Hydraulic System remained above 1200PSI for the whole duration of the recording, it was evident that there was no discrepancy in brakes and they were functional.

The relevant DFDR plots are appended to the report as Appendix 'C'.

1.12 Wreckage and Impact Information

The helicopter after touchdown rolled for nearly 13 seconds and covered a distance of about 300 m on runway before it lifted up again and lost control. The helicopter climbed to about 1680 ft AMSL before descending again while spinning and impacted the ground heavily with vertical acceleration of about 3.5g.

During this process aft section of the tail boom was cut by the main rotor blades and got separated from the main structure. Due to the rotational force, the tail boom along with tail rotor/stabilizer section was thrown far from the main wreckage. The tail section along with tail rotor blades were found at approximately 26 m from the main wreckage. The Main Rotor blades along with head, hub and swash plate was also separated from the structure and was found lying at about 4m behind the main wreckage.

Parts of the main rotor blade, tail section and other structural parts were found scattered around the main wreckage. One of the parts was found as far as 500 m from the main wreckage. This part was probably hit by one of the rotor blades after it came off from its mounting during ground impact. The wreckage distribution plot has been made taking main wreckage as the reference (Refer fig 12. below).

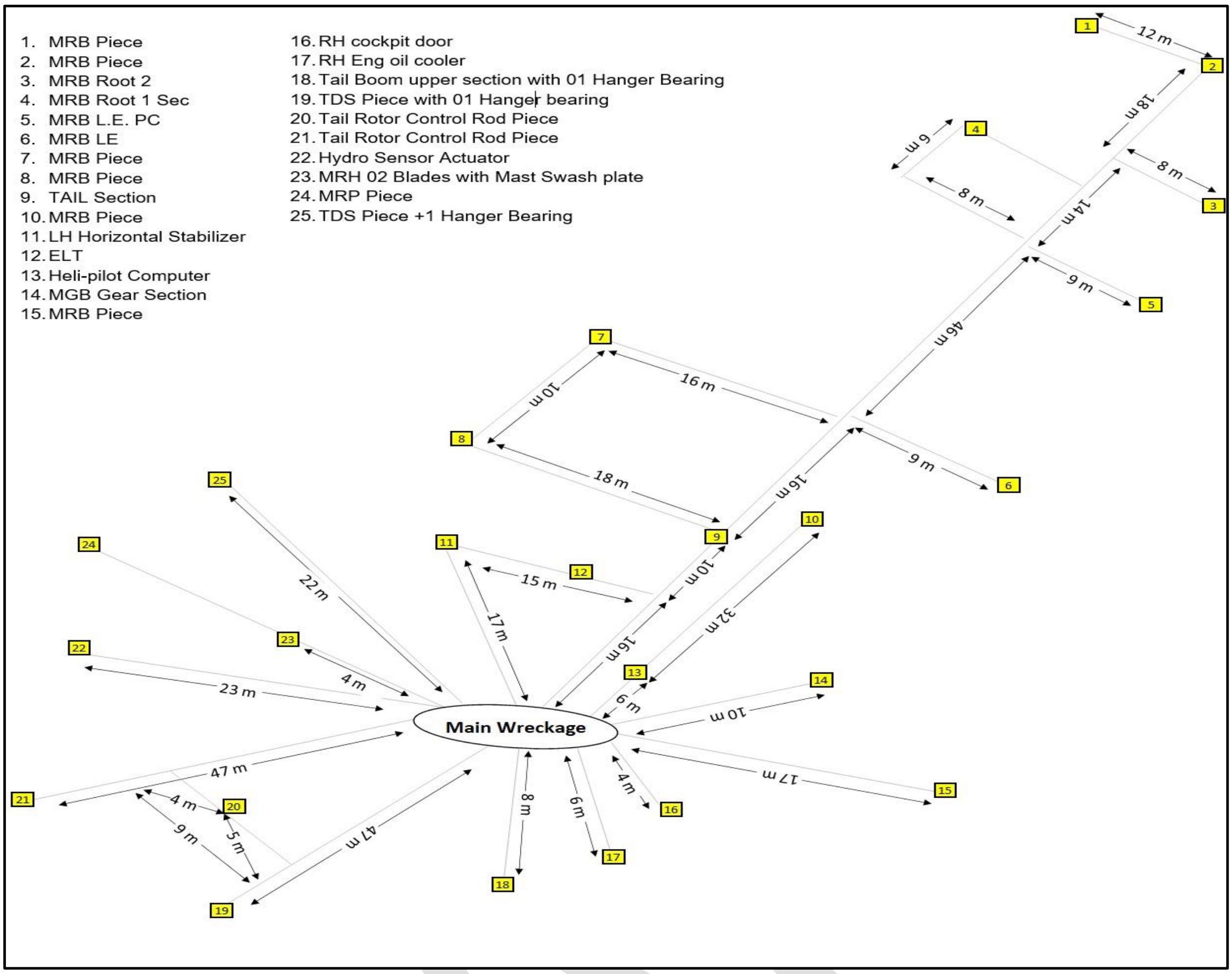

Fig 12: Helicopter Wreckage Plot

Fig 13: Final resting position of the helicopter (Main wreckage)

1.12.1 Damage assessment

Main Rotor: Main rotor Head and mast, Hub, Swash Plate Assembly along with the two damaged, delaminated main rotor blades got disintegrated from the Helicopter and thrown behind the helicopter. The tip and three fourth of the section from the trailing edge of the main rotor blade (serial number N805, Coded Red) was missing. The leading-edge steel protection strip was intact. Three fourth of the section from the tip of the main rotor blade (serial number P856M, coded as blue) was missing. Blade root and mounting was intact. Other two main rotor blades coded as yellow and white were shattered into pieces and scattered around the helicopter main wreckage.

Fig 14: Damaged and separated MGB lying behind main wreckage

Tail Boom: The tail boom got cut by the main rotor blades near the horizontal stabilizer mounting position and thrown to the left side of the helicopter main wreckage. Tail rotor hub and blade assembly was disintegrated with broken Tail Gearbox drive shaft.

Tail Rotor drive shaft, rear long section damaged/bent and found broken into 04 pieces at different places around the main wreckage of the helicopter. Hangar bearings damaged rubber collars separated. Rear bearing was with the rear broken section of the Tail boom and fin section.

Two hangar bearings were with broken pieces of tail drive shaft. One bearing was with the middle broken section of the tail boom and three hangar bearings were with the main fuselage section. Tail rotor control rod found broken into four pieces out of which two pieces were thrown around, one piece was found with the broken tail section and one piece with main fuselage section. Horizontal stabilizers right and left elevators found damaged separated scattered at different places. Right panel detached from the spar tube and LH elevator with two broken pieces of the spar tube. One piece of the spar tube was with the elevator and one with the tail boom section. TGB was intact with the mounting. Pitch change mechanism and tail rotor control rods were attached. Tail rotor hub and blade assembly was attached as single piece, damaged but not disintegrated.

Fig 15: Separated Tail rotor section found 26 m away from main wreckage.

ELT found damaged and separated into four pieces. Main section and front cover found at two different places. Top cover with wires and plug and mounting base found with rear tail section.

Fuselage: Right side of the helicopter main fuselage skin damaged, cracked, torn and crumpled with impact. Fuel tank cap found intact and locked. Baggage compartment damaged, de-shaped. CVDR was intact in the housing but was difficult to remove due to the de-shaped compartment. The main fuselage was tilted to the left at the time of impacting with the ground. Both engines exhaust pipes damaged, buckled and de-shaped but intact with the mounting. High Energy ignition units found intact with mounting. RH engine access panel with engine air particle separator (EAPS) got detached from the mounting, however, quick release fasteners were found intact.

RH side passenger door was detached from the mounting. Plexiglass emergency exit window was intact with door. RH main fuel filter was intact. Service step got damaged. RH side Oil cooler fan was intact with fan belt in position. Engine main drive shafts snapped at both ends with mounting flange broken into pieces.

Hydraulic Tank no. 1 and no. 2 both level shows empty. Hydraulic oil was found splashed around. Both tanks were intact with respective mountings. Main Gear Box top cover found broken into pieces. MGB front mounts with shock struts mounting found broken.

Main landing gear right wheel found intact. Shock strut outer cover was found cracked opened up. Right wheel was stretched outside. RH Cabin and passenger doors were detached and separated.

Nose section: Nose wheel was tilted to right. Nose panel was broken and opened up. Nose mounted electrical components were detached and thrown out. Nose mounted helicopter battery detached along with the mounting base. Heli Pilot SAS 1 and SAS 2 computers, Autopilot computer, Inverters and VOR converters got detached from the nose mountings.

LH Cockpit door was broken, detached from aircraft structure. Instrument panels were damaged and tilted to the right. Both pitot tube were detached from the structure. LH cabin door was completely damage and broken into pieces.

Environment control System (ECS) unit was intact with its mounting. MGB Top cover found broken into pieces, MGB gears, planetary gears were thrown out. Sun gear was with lower section of the MGB. LH MGB mounts was with shock strut with broken piece of the MGB Top cover.

Hydraulic pumps were intact with mounting. MGB mounted accessories, MGB oil filters were intact. LH Hydraulic servo actuator was intact with upper attachment broken. Other two actuators are detached and thrown away.

RH engine right mounting detached from the fuselage section. Both engines were tilted to the Left, rear side. LH engine both front mounts were intact, Rear mount was not visible. Both engine mounted accessories were intact on their respective mountings. Both engine fire extinguishers were intact in the mountings.

1.13 Medical and Pathological Information

Pre-flight breath-analyzer test of the PIC was carried out as per requirement. The breath analyzer test was negative. However, the co-pilot (company pilot) gave a declaration as per DGCA order No. DGCA-15031/4/2020-DAS dated 11 March 2022 that he did not consume alcohol or any psychoactive substance in the last 12 hours from the time of reporting for the duty.

Both crew received fatal injuries and after the accident, their post-mortem was carried out in Raipur. As per the post mortem report, the cause of death of both crew was given as "*Hemorrhage & shock as a result of multiple injuries to his body*".

1.14 Fire

There was no Fire.

1.15 Survival Aspects

The accident occurred inside the aerodrome and the site was easily accessible. As the helicopter had already declared the technical problem and asked for priority landing, the fire tenders and ambulance were positioned at PD position. After the helicopter crashed, the emergency services like rescue team, fire tender and ambulance reached the accident site immediately. Both crew were rescued from the helicopter after opening the seat harness by the rescue team & fire personnel. The company pilot (co-pilot) who was occupying the right seat was rescued first by the fire personnel by breaking the door manually. However, as the helicopter crash landed slightly on its left side, which made it difficult and took considerably more time to rescue the other pilot (PIC) who was occupying the left seat. They were immediately taken to the hospital where they were declared brought dead i.e., both the crew did not sustain the injuries caused due to the heavy impact of helicopter with ground. There was no delay in the rescue operation.

1.16 Tests and Research

1.16.1 Failure analysis of damaged helicopter components.

The wreckage examination was carried out in Raipur after the accident with the help of representative from OEM i.e., Leonardo Helicopters (LH). After the wreckage examination some of the components/parts like tail rotor hub assembly, tail rotor blade, tail rotor drive shaft, pitch control rod assembly and Upper case MGB were retrieved from the wreckage for further detailed examination in order to identify the cause of its failure and its serviceability. The components were shipped to Leonardo helicopters facility in Italy.

Following tests/examinations were carried out at LH facility on the components retrieved from the wreckage: -

- Macroscopic and stereo-microscopic examinations of the surfaces of all parts;
- Stereo-microscopic examination and scanning electron microscope (SEM) examination of some selected fractures of the MR gear box upper case, the TR drive shaft and the output shaft of the TR gear box assembly;
- Semi-quantitative analyses of the chemical elements by energy dispersive X-ray spectroscopy (EDS) through the SEM on some debris collected from the TR gear box magnetic chip detector.

Furthermore, some maps and semi-quantitative analysis of the chemical elements were also performed by EDS in some areas of the outboard locking nut and the support bearing sleeve assembly.

The salient observations during the failure analysis of these components are given below: -

a. Main Rotor Gear box upper case

The MR gear box upper case was fractured in numerous parts partially covered with soil. All fracture surfaces were macroscopically very rough a typical feature of overload failure. Given the common macroscopic appearance of the fracture surfaces, it was agreed to observe only one of them under the SEM as representative of all others. Given the common macroscopic appearance, a small part was observed under the SEM. The observed morphology is characterized by a mixture of grain separation and dimples typical of the overload failure.

The collected evidences suggest that the upper-case failed impacting with the ground.

b. Tail Rotor drive shaft assembly

The drive shaft assembly was fractured from various positions. Three parts were retrieved for examination. These were heavily deformed and partially covered with soil. All fracture surfaces were macroscopically very rough, a typical feature of overload failure. Given the common macroscopic appearance of the fracture surfaces, it was agreed to observe only one of them under the SEM as representative of all others.

One of the parts was observed under the SEM. The observed morphology is characterized by the dimples typical of the overload failure.

The collected evidences suggest that the drive shaft deformed and failed impacting with the ground.

c. Tail Rotor Gear box assembly

The TR gear box assembly was overall intact, with the exception of some cracks in the case sealant and some deformed bolts likely due to the impact with the ground. Furthermore, the output shaft was fractured and missing of the toothed part remaining engaged in the TR hub, but was free to rotate.

The oil level appeared regular, as shown by the appropriate indicator. After removing the oil and disassembling the gear box, three teeth of the input pinion spiral bevel gear and three teeth of the bevel ring gear were found chipped, with some fragments lost. The two parts are engaged during normal gear box operation so it is reasonable that they collided and damaged each other when the helicopter hit the ground. The larger debris collected from the magnetic chip detector was subjected to a semi-quantitative analysis of the chemical elements by EDS through the SEM, which detected a composition compatible with the steel alloy of the two parts, excluding the possibility that foreign particles may have entered the box causing malfunctions.

After separation from the TR hub, the toothed part of the output shaft was cleaned of the partially covering soil and the fracture surface was analyzed. It was macroscopically rough and observed under the SEM, showed the microscopic dimples typical of the overload failure. These evidences suggest that the output shaft failed after impacting with the ground.

d. Tail Rotor

i. Tail rotor disassembly

After opening the shipping box, the tail rotor was disassembled in order to inspect the single parts in detail. The main considerations and checks made during this operation are listed below. The photographs of the observations made in this section are enclosed in Appendix B: -

- The washer to be fitted under the locking nut of the special hub plug (mating to the balancing flange) in accordance with the maintenance manual, was not installed (Figures 1 and 2 of App B).

- The balancing flange had some washers applied to four holes close together (Figures 1 and 3, App. B). The maintenance manual states that balancing must be performed by applying appropriate masses to the flange using a combination of washers, nut and bolt in up to four positions (four holes in the flange), without exceeding the weight of 25 grams (including nut and bolt) for each position. The weighing of the masses in the laboratory (Figure 3 of App. B) on each position did not reveal any anomalies.

- It was verified that the blades were free to rotate around their longitudinal axes (Figures 1 and 4, App. B).

- The washer to be fitted to both the hub flange assemblies (Figures 5 and 6, App. B) in accordance with the maintenance manual was not installed on the outboard side. Instead of the required washer, two thinner and smaller in diameter washers were installed.

- The thickness of the shims installed under the two hub flange assemblies (Figures 5 and 7, App. B) were measured in laboratory with a micrometer, because the maintenance manual requires them to be equal. The manual allows for the grinding of the non-chamfered side of the shims to obtain equal thicknesses. One of the shims has not been grinded and has a constant measured thickness value of 2.667 mm, while the other has been grinded and has a measured thickness value as a function of the area examined, which varies between 2.475 and 2.510 mm.

- The disassembly of the half scissors connecting the slider assembly to the sleeve assembly (Figures 8 and 9, App. B) revealed the application of a tightening torque to the nuts (measured values in Figure 9, App. B) not indicated in the maintenance manual, which only provides for their gentle tightening up to the elimination of the axial play of the links. Furthermore, the extracted bolts showed considerable wear damage, with great alteration of their geometry due to the material loss (Figure 9, App. B).

ii. Tail rotor rotating parts detailed inspection

Figure 10 of appendix B shows some drawings of the assembled tail rotor rotating parts, which will be helpful for understanding the observations and considerations reported in the following paragraphs where each of them has been inspected in detail.

➢ **Slider assembly**

- The slider assembly (Figures 8 and 10, App. B) shows large wear areas on the pitch link arms. They extend from the slider central body towards a circumferential edge corresponding to that of the outboard locking nut when in contact with the slider central body (Figures 11 and 12, App. B). The wear morphology is consistent with a rub reasonably occurring with the edge of this locking nut. This evidence suggests that the outboard locking nut came off the support bearing sleeve assembly (Figures 8 and 10, App. B) and revolved around the slider central body. This hypothesis is confirmed by the presence of some circumferential linear marks on the lateral surface of the central body of the slider in positions compatible to inner surface relief elements of the locking nut, when the latter is in contact with the pitch link arms (Figure 13, App. B).

- The inner surface of the slider was covered with a large amount of dark powder from the heavily worn lining of the inner bushing (Figure 14, App. B), which leaves a small portion of the underlying web exposed (Figure 15, App. B). Furthermore, the bushing was found completely detached from the slider inner surface (Figure 15, App. B).

- After cleaning, the slider inner surface showed towards the inboard side two nearby areas characterized by a multitude of short circumferential nicks that affect about 2/3 of the circumference (Figure 16, App. B). Two areas with similar features are also present on the outer surface at the inboard side edge of the corresponding sleeve (Figure 17, App. B), witnessing that the two parts came in contact in service.

- These nicks could be a result of the locking nut coming off the support bearing sleeve assembly. In fact, the first consequence of this is the disassembly of the duplex bearing and therefore the loss of coaxiality between the slider and the sleeve, as well as the loss of pitch control, due to the absence of connection between the slider and the support bearing sleeve assembly. In this condition, the slider may have repeatedly tilted with respect to the sleeve, coming in contact with it.

- Instead, the condition of the bushing does not appear to be a consequence of the loss of pitch control, as the absence of connection between the slider and the support bearing would have resulted in the impossibility of axial sliding between the slider and the sleeve, making the development of wear impossible. Consequently, it would seem more plausible to assume that wear and bushing detachment occurred independently from the event, but they could be evidence of poor maintenance. In fact, the maintenance manual requires to check the bushing lining for wear and to replace the bushing if the underlying web becomes visible.

➢ **Outboard locking nut**

- The outboard locking nut (Figures 8 and 10, App. B) as arrived in the laboratory was completely covered by soil-rich duplex bearing grease and missing of the locking wires (Figure 18, App. B).

- After cleaning with methylethylketone (MEK) first using a toothbrush and then an ultrasonic bath, the nut was almost completely brown in color due to generalized oxidation (Figure 19, App. B), indicating the loss of the protective cadmium plating which could be a consequence of the manipulations of the part in the various tail rotor installations. Only the threaded part and the inboard edge have kept the color of the steel, being more isolated from the atmospheric environment. Furthermore, even the edges of the inner surface relief elements retained the color of the steel (Figure 19, App. B) having come in contact with the central body of the slider assembly after the nut came off the support bearing sleeve assembly, as explained in the previous paragraph. The almost complete absence of the cadmium plating and the generalized oxidation were verified by EDS analysis (Figures 20 and 21, App. B).

- The generalized oxidation of the nut could indicate poor maintenance. In fact, the maintenance manual provides for inspecting all tail rotor parts for any evidence of damage or corrosion.

- The grease removal also allowed to verify the presence of the thread locking adhesive (Loctite® 222) in the nut as requested by the maintenance manual. No residues of it were observed (Figure 22, App. B) so it probably was not applied in the last assembly operation.

- The surface of the outboard edge of the nut appears rubbed and crushed, reasonably for the impact / slipping with the pitch link arms of the slider assembly (Figure 23, App. B), according to the hypothesis described in the previous paragraph.

- The nut threads do not show relevant damages (Figure 24, App. B). Only the two threads towards the inboard side and particularly the inboard side edge of the nut show crushed areas and oblique nicks (Figure 24, App. B), which could be due to the impact / slipping with the outer ring of the outboard bearing belonging to the duplex bearing, when the locking nut came off the support bearing.

- All the nut holes for fixing the locking wires have been used in the various tail rotor installations, as their edges and the corresponding areas of the nut outboard edge are worn from the repeated relative rubbing with the locking wires in the vibratory environment (Figure 25, App. B). All the worn areas are brown in color due to the generalized oxidation, with the exception of two holes, placed at 180° from each other, which were probably used in the last installation. This observation confirms that the locking wires were probably applied in the last assembly, even if they have not been found.

➢ **Support bearing sleeve assembly**

- The support bearing sleeve assembly (Figures 8 and 10, App. B) arrived in the laboratory with the inner surface completely covered by soil-rich duplex bearing grease and missing of the locking wires (Figure 26, App. B). The support bearing was subjected to a cleaning with methylethylketone (MEK) first using a toothbrush and then an ultrasonic bath.
- The threads and the duplex bearing seat completely lost the yellowish color of the chromate conversion treatment required by the drawing (Figures 27 and 30, App. B), probably due to the manipulations of the part in the various tail rotor installations. The almost complete absence of this conversion was verified by EDS analysis (Figures 28 and 29, App. B).
- As for the outboard locking nut, no residues of the thread locking adhesive (Loctite® 222) required by the maintenance manual were observed in the support bearing thread (Figure 30, App. B) so it probably was not applied in the last assembly operation.
- The duplex bearing seat shows no significant damages at the surface mating with the inboard bearing while a multitude of circumferential marks and deep inclined nicks on the surface that fits the outboard bearing (Figures 27 and 30, App. B). These nicks also affect the entire thread length (Figure 30, App. B). Furthermore, a significantly crushed localized area was identified, which involves both the outboard bearing seat and the thread adjacent to it (Figure 31, App. B).
- The counterpart which impacted / slipped with the bearing seat and the thread causing the above damage was not likely the outboard locking nut for installation and size reasons, as its thread is screwed into that of the support bearing. The only possibility of the nut impacting is that it has previously teared the support bearing threads along their entire circumference, but this is to be excluded as the threads appear overall intact, maintaining their original trapezoidal profile required by the drawing (Figure 32, App. B).
- For dimensional reasons, the outboard bearing outer ring may have been the main responsible for the observed damage. In fact, the quite circumferential marks of the

support bearing seat were probably due to the rotation of the outer ring inside it, which necessarily took place together with the unscrewing of the outboard locking nut (a representation of this is in Figure 33, App. B). The absence of damages on the surface mating with the outer ring of the inboard bearing indicates that it has moved less than that of the outboard bearing.

- The inclined nicks occurred once the locking nut was completely outside the support bearing. In fact, this caused the definitive disassembly of the outboard bearing and the displacement of its outer ring in the support bearing threaded area, which it impacted several times, rotating and tilting repeatedly (a representation of this is in Figure 33, App. B). The area with the significant crushing could be the result of a very strong impact / sliding of the ring occurred when the aircraft impacted the ground.
- The outboard edge of the support bearing show crushed areas and inclined nicks (Figure 34, App. B), reasonably due to impact / slipping with the unscrewed outboard locking nut in revolution around the slider assembly central body.
- Large nicks are also visible on the side surface of the support bearing shoulder mating with the inboard bearing (Figure 35, App. B). They necessarily originated due to the impact / slipping with the relief elements of the inboard locking nut, which also show similar damages (Figure 36, App. B). The parts could only have come in contact if the slider had tilted with respect to the sleeve assembly axis, thus if the pitch control had been lost due to the outboard locking nut coming off the bearing support. Therefore, the nicks are a consequence of this.
- The holes for fixing the locking wires shows worn areas due to the repeated relative rubbing with them, located at their edges, their sides and the support bearing outboard edge (Figure 37, App. B). The large extent of the wear zones could testify that large relative movements occurred in the vibratory environment, maybe favored by the loss of the locking nut tightening torque.

➢ **Duplex bearing**

- The duplex bearing (Figures 8 and 10, App. B) arrived in the laboratory with the outer rings separated from the inner rings, which were still attached to the slider assembly (Figure 38, App. B). In fact, they freed from the slider assembly in the event, due to the failure of the TR gear box output shaft and the outboard locking nut coming off the support bearing sleeve assembly. Furthermore, Seegers, seals, cages and balls (Figure 39, App. B) were lost.
- All rings were covered by soil-rich grease (Figure 40, App. B), therefore they were cleaned before using paper and then an ultrasonic bath of methylethylketone (MEK).
- After removing the inboard locking nut to extract the duplex bearing inner rings, it was verified that they were assembled according to the maintenance manual. The rings were oriented correctly as the engravings on them could form a V-shaped mark, but unlike the maintenance manual, the engravings were not aligned with each other (Figure 41, App. B). This misalignment could be due to the installation of the duplex bearing or could have occurred during the event.
- It was not possible to perform a similar check on the outer rings as their installation position on the helicopter is unknown, having been lost in the event. However, since it is impossible for size reasons to reverse assemble the outer rings when the inner ones are

assembled correctly, it is reasonable to assume that the outer rings also formed the V-shaped mark correctly.

- The races and the surface of the shoulders at their two sides of all rings are characterized by a multitude of impact / slipping marks (Figure 42, App. B). They were reasonably due to the movements that the outer rings were able to make once the locking nut had disengaged from the support bearing, resulting in repeated contacts with the inner rings, slider and balls before they were lost.
- One of the outer rings is particularly damaged, so it probably belonged to the outboard bearing. In fact, the outboard bearing outer ring has the possibility of occupying the threaded area of the support bearing, where it can also come in contact with the raised elements of the slider, as evidenced by the compatible damages observed thereon (Figure 43, App. B).
- No significant damages have been observed on the external surfaces of the outer rings as their steel alloy has a higher hardness than the aluminum alloy of the support bearing, with which they came in contact, as described in the previous paragraph.

1.16.2 Engine Electronic Controller (EEC) Unit

EEC units for both engines were retrieved from the helicopter and shipped to Pratt & Whitney (OEM of Engines in the helicopter) in co-ordination with TSB-Canada to retrieve data from the units at Pratt & Whitney facility in Canada.

Both the EEC units were in normal condition for data download. The EEC's raw data was downloaded and recorded in a .FLP file format. The downloaded files were then converted conversion to a readable format.

The PW206C EEC are capable of recording fault and these faults are associated with the corresponding engine Ng (Compressor speed / N1) speed at time of the fault occurrence. The faults are stored into the EEC Electrically Erasable Programmable Read Only Memory (EEPROM) to a specific address. These addresses were validated and reviewed by the P&WC control System team, and all the reviewed addresses were at 0.

However, it was concluded that the EEC download data did not provide fault code recordings prior to or post impact.

1.16.3 Engine

Both Engines were examined by the Investigation team in association with representative of OEM at Raipur. Physical examination and borescope inspection of the engines in-situ was carried out.

Following observations was made during the examination: -

- The engine compartment including fire walls were damaged. Output shaft on airframe side of both engines were sheared. However, output shaft of both engines were free to rotate. The exhaust tail pipes of both the engines were badly deformed.

- **<u>LH Engine</u>**

- Fuel Control unit, Data Collection unit, Starter Generator were all intact. Engine inlet screen was slightly deformed. Starter Generator was removed to facilitate installation of drive tool to rotate the impeller and compressor turbine. Fuel nozzles were removed to accomplish Borescope Inspection.
- Impeller was free to rotate. BSI of Impeller revealed few nicks on it's vane which looked to be pre-existing prior to the event.
- Compressor Turbine (CT) was free to rotate. BSI of CT revealed no damages or abnormalities. All blades were intact with no obvious damages. CT Shrouds did not exhibit any rub marks.
- Power Turbine (PT) was free to rotate. Inspection of PT from exhaust end revealed no damages or abnormalities. All blades were intact with no obvious damages.

- **<u>RH Engine</u>**

- Fuel Control unit, Starter Generator were all intact. Engine inlet screen was slightly deformed. Starter Generator was removed to facilitate installation of drive tool to rotate the impeller and compressor turbine. Inlet Screen and Fuel nozzles were removed to accomplish Borescope Inspection.
- Impeller was free to rotate. BSI of Impeller revealed few nicks on its vanes that looked to be pre-existing prior to the event.
- Compressor Turbine (CT) was free to rotate. BSI of CT revealed no damages or abnormalities. Few blades were wet with oil. All blades were intact with no obvious damages. CT Shrouds did not exhibit any rub marks.
- Power Turbine (PT) was free to rotate. Inspection of PT from exhaust end revealed no damages or abnormalities. All blades were intact with no obvious damages.

1.17 Organizational and Management Information

Directorate of Aviation, Government of Chhattisgarh is a State Government organization approved by DGCA under State Government Operating Permit No: 08/2012. As on date of accident, the organisation was operating only one helicopter i.e., the accident Helicopter VT-CHG. Apart from this, it also has one King Air B200 fixed wing aircraft. Main base of operation for Agusta 109E helicopter is Police Ground, Raipur and for King Air B200 aircraft it is Swami Vivekanand Airport, Raipur. Civil Aviation Department (CAD), Govt. of Chhattisgarh (GoCG) is a Government of Chhattisgarh undertaking carrying out Flying Operations since 2003.

The organisation chart of the operator is given below: -

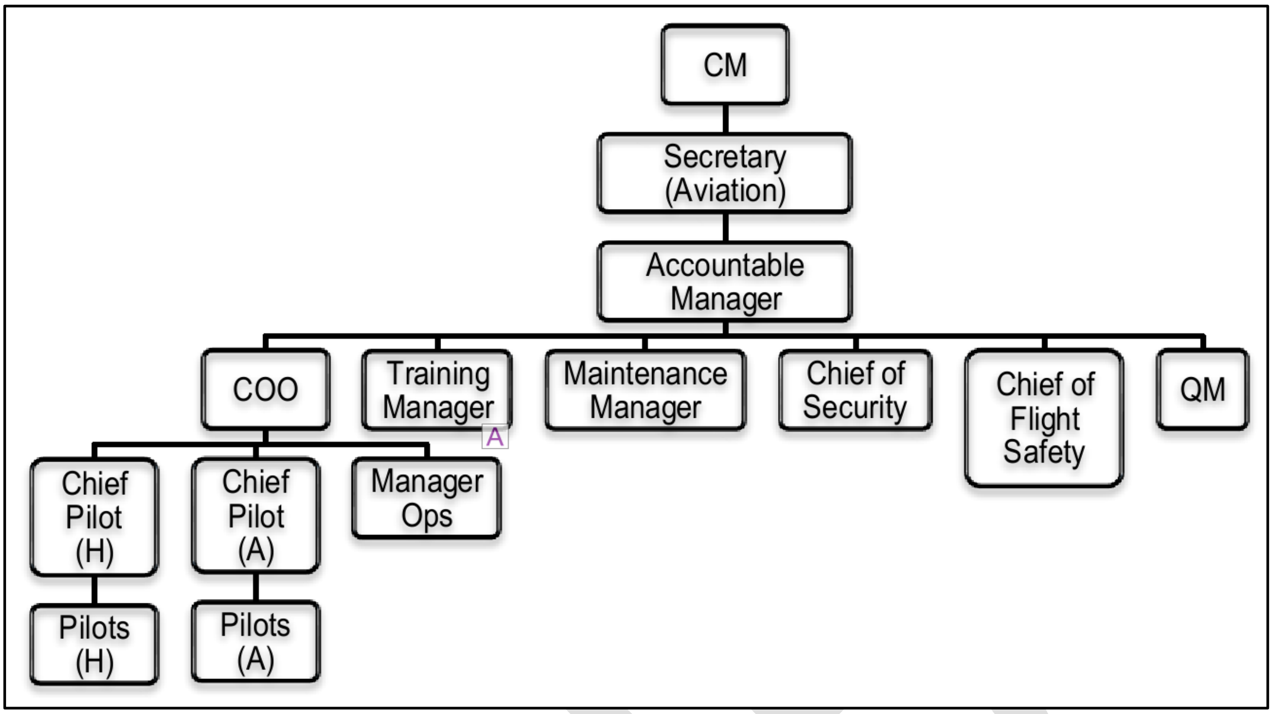

Fig 16: Organisation Chart of Civil Aviation Department, Government of Chhattisgarh.

As per the operations manual of the organisation, COO will be responsible for overall supervision of Flight Operations. He will be assisted by Chief Pilots of respective aircraft and the Operations Manager.

1.17.1 Operations Manual of Organisation

The organisation has formulated an Operations Manual which is approved by DGCA in June 2018.

1.17.1.1 Duties & Responsibilities of various post holders

- **Accountable Manager**

The Accountable Manager is a person who has the overall (including financial) responsibility for running the organization on a full time basis. He is responsible for formulating a system to run the organization and adhering to the system requirements and prevents system lapses. He has the authority to execute decisions/plans. In long absence of designated Accountable Manager, an Alternate Accountable Manager (normally the COO or in his absence any one of the two Chief Pilots) will take over his responsibility during his absence. Any change in the Accountable Manager at any time will be intimated to the DGCA along with the details of new Accountable Manager.

The duties and responsibilities of Accountable Manager encompass:

(a) Ensuring that all relevant requirements and regulations of DGCA are complied with.
(b) Organize, manage and supervise all activities including quality monitoring, within the organization including contracting and surveillance regarding subcontracting work.
(c) Direct proper quality control setup to ensure and enable maintenance in accordance with the organizations, manufacturers and relevant DGCA requirements.

(d) Provide premises and ensure that office accommodation appropriate to the management of the work is available.
(e) Ensure that appropriate instructions are developed, maintained, documented and followed for compliance with the requirements including payment of any charges.
(f) Provide staff and ensure that all personnel are appropriately trained and qualified to accomplish the work.
(g) Ensure that all maintenance work is suitably recorded as per the requirements
(h) Provide suitable facilities to enable the organization to work as per the scope of approval granted.
(i) Provide finance for necessary components, spare parts, materials etc. and ensure proper control over purchases, receipt, storage, safekeeping, and dispatch.
(j) Provide updated Instructions/ Manuals/ Circulars, for the work to be performed which includes all necessary material/data from the applicable Aviation Authorities and the aircraft manufacturer as appropriate.

- **Chief of Operations**

All operational planning and detailing will be looked after by Chief of Operations. He will also monitor the day-to-day safety regulation and in house monitoring of the flight operations through the Chief Pilots, Pilots, Operations Officers. CAD, GoCG will maintain a proper system of documentation and record keeping of the deficiencies observed and the corrective measures taken. He with his operations team will be responsible for carrying out the duties as mentioned below.

(a) Liaise with the engineering section and confirm availability of the helicopter in time for the proposed flight.
(b) Obtain all necessary clearances / permissions as required prior to operation of the flight.
(c) Brief the Flight Crew of flight support arrangements such as Ground Handling, Fuel, Catering, Landing permissions, Watch hours, VVIP/VIP movements, Air Defense Clearances and other allied information.
(d) Monitor the flight progress and coordinate with respective agencies.
(e) Handle unexpected delays / cancellation of flights, if any.
(f) Take all decisions with respect to operations of GoCG aircraft.
(g) Keep Accountable Manager informed about all matters, which require his attention.
(h) Provision of statistical returns to DGCA on monthly basis.
(i) Overall responsible for implementation of the flight operations policy & procedures in the operations manual.
(j) Monitor data recorded on the flight recorders (CVDR) for:
    I. performance monitoring of the flight crew,
    II. early detection of safety hazards, and
    III. initiation of appropriate accident prevention measures.
(k) Ensure adequate manning of Operations Offices by appropriately trained Operations and other supporting staff. The strength of such staff shall have to be increased as the size of operating fleet grows.

- **Chief Pilot(H).**

Chief Pilot(H) will be directly responsible to the Chief of Operations in all matters pertaining to Flight Operations of respective fleets. He will be responsible for the following: -

(a) Ensuring that the helicopter operations are conducted incompliance with the Aircraft Rules 1937, Civil Aviation Regulations and various Circulars issued by DGCA, India.
(b) Planning of Flight Crew through strict adherence to Flight Duty Time Limitations as per DGCA, India.
(c) Monitoring of Licenses and Ratings records for each Flight Crew including Validity, Recency or Limitations, if any.
(d) Ensuring that all flight crew have taken Dangerous Goods training.
(e) Ensuring that a library of all operational documents is maintained up to date.
(f) Crew pairing /selection of Flight Crew keeping Human factors in Mind.
(g) Acclaiming updation of all technical documents including the OM and Flight Crew Check list based on the revision issued by OEM/Regulatory Authorities & based on Accident/Incident analysis & Safety Audits.

- **Maintenance Manager.**

The Maintenance Manager is the nominated post holder for Maintenance and directly reports to the Accountable Manager on all aspects and activities of the Engineering Department. The duties and responsibilities include, but not limited to: -

(a) Overall functioning of the engineering department in an efficient manner to achieve safe aircraft operations.
(b) Liaising with Operations Department for all activities pertaining to operation of all aircraft.
(c) Procurement of necessary tools, equipment, and literature.
(d) Manpower planning, functioning of maintenance facilities and offices.
(e) Preparation and monitoring of maintenance programs, work packages, MEL and other technical documents,
(f) Analyze all airworthiness information provided by the manufacturer / DGCA and take necessary implementation actions.
(g) Maintaining Tech library with required & adequate documents, books & reference material.
(h) Coordinate with the Quality Manager and extend full cooperation and help for timely implementation of all the instructions, directives, modifications & service bulletins.
(i) Provide support for effective implementation and running of safety management system.
(j) Responsible for future planning and expansion programs and looks into manpower, materials, and tool requirements for such expansion.

- **Chief of Flight Safety**

The Chief of Flight Safety reports to the Accountable Manager on all matters related to Flight Safety. He / She shall be responsible for implementation of the policies and procedures for compliance of safety requirements in the Flight Safety Manual. All personnel in the organization shall give the Chief of Flight Safety (CFS) such assistance in his functioning as Chief of Flight Safety may deem necessary. He may make recommendations on any and all activities related to aviation safety within all sections of the organization. Among his responsibilities are as follows: -

(a) The CFS shall analyze incidents, defects, carry out internal safety audits and monitor Flight Operations Quality Assurance by downloading flight data recorder information.
(b) Liaise with the Chief pilot to ensure that flight planning is done proactively to preclude breach of FDTL regulations.
(c) Report Breath Analyser (BA) positive cases to DGCA (HQ) And Regional Offices within 24 hours.
(d) Manage the CAD, GoCG Flight Safety Program;
(e) Determine standards and methods for use in trend analysis suitable for use in the Flight Safety Program in cooperation with the Chief pilot;
(f) Assist the Accountable Manager by making those inputs as necessary in his function of performing risk management in flight operations;
(g) Monitor adherence to established safety standards and identify undesirable trends in operational/technical areas with regards to flight safety and to report any such findings to the Accountable Manager.
(h) Inspect and examine any area of the operations, as necessary, which may have an impact on flight safety and to report any deviations from safe practices to the Accountable Manager.
(i) Establish and monitor appropriate procedures for the handling of any reports having an impact on flight safety.

As on date of accident, the post of Chief of Flight Safety was vacant. The organisation had proposed one of their senior pilots for the said post which was under approval by DGCA.

1.17.1.2 Chapter 6 of the Operations Manual

This chapter provides Standard Operating Procedures for helicopter operations. Some of the relevant procedures are appended below: -

6.4.4: Pilot-in-command shall accept the helicopter by signing in the acceptance form of FRB. A copy (white) is to be removed and handed over to engineering as a record of acceptance.

6.4.5 On completion of the flight, pilot-in-command shall enter all relevant details in the FRB regarding flight sector, block times, number of Landings, flight duration, engine cycles monitoring data and defect if any or nil and handover the log book to engineering. This is to be followed after termination of each flight at base.

6.4.6 In case of subsequent flights from main base of the same day with different flight crew, then pilot-in-command of subsequent flights shall sign again in acceptance form.

16.13.5 Handing Taking Over of Controls. At any time that control is transferred from one pilot to the other, each pilot must acknowledge the changeover verbally, using the specific words.

(a) “You have the controls, maintain heading…., altitude……”, and the other pilot answers “I have the controls”
(b) The new non-flying pilot should raise his arms noticeably to confirm that he has given up control of the aircraft.
(c) Either Pilot Flying (PF) or Pilot Monitoring (PM) may initiate transfer of control. However, in case of doubt or conflict the PIC shall have final authority over who has the control of the helicopter.

1.17.1.3 Chapter 10 of Operations Manual

This chapter provides information/procedures regarding Accident/Incident Considerations. Some of the relevant procedures are appended below: -

Para 10.3 Flight Safety Program

Modern investigations delve into incidents/accidents much more deeply to find all of the casual factors of the event, both, in the performance of the individuals involved and those inherent in the system.

A flight safety program has a main goal of accident/incident prevention and a secondary goal of preservation of State Govt. resources. It has two aspects, positive and negative.

Positive	**Negative**
Leadership	Investigation
Education	Crisis Management
Training	Follow-up reporting
Risk Identification	
Safety Program Management	

The positive aspects are geared to the prevention of accidents/incidents by means of finding indicators that something undesirable is going to happen and the nature of the upcoming event. The negative aspects are geared towards preventing a second or subsequent occurrence of the same type of event.

A safety program endeavors to:

(a) Have commitment from the Government;
(b) Involve Directorate;
(c) Enforce supervisory performance; Have employee participation; and
(d) Be flexible.

The goal of the flight safety program is the systematic discovery, evaluation and elimination of hazards to flight. It is preventive in nature and will be systematically developed and improved based on active inputs from all individuals involved.

For any flight safety program to be of value, all individuals must actively seek to aid in the fulfilling the purposes of the program.

As on date of accident, no such safety programme was conducted in the organisation.

1.17.1.4 Chapter 11 of Operations Manual

This chapter provides Personnel Qualification and Training procedures. Some of the relevant procedures are appended below: -

Para 11.3 Recurrent Training

…….

(b) Helicopter/ flight simulator training. All pilots shall undergo recurrent training at least once in two years at Leonardo Helicopters, Italy or on any other a FFS Level B/C/D or FTD 6/7 (FAA Designation), which has been approved by DGCA for training on A-109E helicopters. Instrument Flying and the practice of those parts of emergencies such as touchdowns in engine failure, hydraulic failure, multiple system failures, tail rotor failure/control failure, loss of tail rotor effectiveness (LTE), Vortex Ring etc which cannot be practiced in actual flying shall be carried out. All major failures of systems and associated procedures shall be covered in a period of two years. Minimum duration shall be 8:00 hrs. (4:00 + 4:00 hrs of IF + Critical Emergencies).

…….

Para 11.4 Flight Recurrent Checks

………

(c) Night Flying / Route Check. All pilots are to complete at least 05(five) take offs and landings by night, and one route check by night, in the last six months immediately preceding the date of intended flight. All efforts are to be made for planning night flying as required to maintain the currency of all pilots flying VT-CHG. The night route check shall comprise a route / triangular nav of minimum 100 nautical miles. Night flying checks and Night Route Check may be carried out in the FFS Level B/C/D at any other DGCA approved ATO. All efforts are to be made for planning night flying as required to maintain the currency of all pilots flying VT- CHG. In case the currency of night flying is lapsed, a PPC sortie with TRE/TRI is to be carried out for at least 0:45 hrs. with 05 take-offs and landings before undertaking Night Flying Operations in State Helicopter.

……….

1.17.1.5 Chapter 16 of Operations Manual

This chapter provides procedure for Safety Monitoring CVR & FDR. Some of the relevant procedures are appended below: -

……

16.1.2 CAD, GoCG shall appoint a DGCA Approved Maintenance Agency for the Analysis of the CVDR of State Helicopter. This agency shall undertake Engineering Parameters Evaluation and Flight Operational Quality Assurance (FOQA) analysis of CVDR (CVR and FDR) of VT-CHG every quarter and as and when requested.

……..

16.3 FDR Analysis

16.3.1 The FDR is capable of recording 25 hours of data.

16.3.2 The downloading of FDR data is to be done every quarter, or as required for any special reason/observations to ensure that all flying data is recorded.

16.3.3 CAD, GoCG shall outsource FDR Analysis to an agency having DGCA Approved software for analysis.

16.3.4 Procedure of Analysis.

(a) Read out of CVR and FDR. Read out in RAW format is to be provided to CAMO by CAR-145 Maintenance Agency.

(b) QM-GoCG will submit the CVR readout to CFS, GoCG for analysis.

i. If voice recording is inappropriate, CFS shall send the data to CAMO for clarification from CAR-145 agency. If required, CAMO will issue work order for undertaking fresh readout.

ii. If voice recording quality is satisfactory, CFS will accept the readout for further processing.

(c) After acceptance from Chief of flight safety, CVDR data for FOQA shall be done by Flight Safety Department, GoCG.

(d) After download entire data shall be analyzed to determine if any flight parameter had exceeded the laid down limit. If any exceedance is detected, a report giving the actual value of the parameter, the specified limit for the same, the time of the event and the other relevant flight details. A report for the exceedances of parameters for each flight shall be generated and forwarded by the contracted agency to CFS CAD-GoCG for review and flight analysis.

(e) Appropriate reports are to be submitted in accordance with para 5 of CAR Section 5, Series F part II.

The investigating team perused the FDR data analysis reports for the last few years provided by the organisation and it has been observed that there have been no exceedances found during the analysis of these data.

1.17.2 Flight Safety Manual

The organization has formulated a flight safety manual. However, the investigation team observed that the flight safety manual was last approved by DGCA in the year 2011.

The operator re-submitted the flight safety manual to DGCA after making amendments complying with existing regulations. Since then, there have been number of communications made between the operator and DGCA regarding approval of the flight safety manual. The last communication was made by the operator in Nov 2021 wherein they had submitted the revised manual based on the latest observations made by DGCA vide e-mail dated 05 Oct 2021. However, till the date of accident, the flight safety manual is not approved by DGCA. The investigation team obtained the latest flight safety manual submitted by the operator. Relevant portion of the flight safety manual are appended below: -

1.17.2.1 Chapter 3 of Flight Safety Manual

This chapter provides procedure for Aircraft Accident / Incident Reporting. Some of the relevant para is appended below: -

(I) Accident and Reporting Procedure

Rule 18 of Aircraft (Investigation of Accident and Incident) Rules 2017 provides for the reporting of the occurrences to DGCA and AAIB. Rule 18 of Aircraft (Investigation of Accident and Incident) Rules 2017 requires DGCA to establish a mandatory reporting system to facilitate collection of information on actual or potential safety deficiencies. Rule 13(1) of Aircraft Rules 2017 empowers the DGCA to institute investigation into incidents and in case of serious incidents wherein the aircraft AUW is below 2250 kg and is not a turbojet aircraft.

The detailed objectives of the incident/occurrence reporting systems are:

(a) To enable assessment of safety implications of each occurrence, including previous similar occurrences, so that any necessary action is initiated to prevent similar occurrences in future.

(b) To ensure dissemination of information. DGCA will evaluate each occurrence report received to decide which occurrence require investigation by the DGCA or by the concerned operator /AAI through PIB/AIB under the supervision/convenorship of the DGCA.

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

Incidents shall be investigated by the Permanent Investigation Board of the DOACG under supervision of Officer of the Regional Air Safety Offices.

NOTIFICATION: The notice and information of occurrences as listed in para iii of this chapter in the prescribed format shall be sent as soon as possible by the quickest means available and in any case within 24 hours by the Chief of flight safety to the Director General of Civil Aviation (Attn: Director Air Safety, HQ) and the concerned Regional Air Safety Office (WR). In addition, the information regarding accident shall also be provided to Aircraft Accident Investigation Bureau (AAIB).

1.17.2.2 Chapter 4 of Flight Safety Manual

This chapter provides procedure for Aircraft Accident / Incident Investigation. Some of the relevant para is appended below: -

B. Investigation of Serious Incident and Accident

(i) Authority issuing order for the Investigation of Accident and serious Incidents. Central Government/Director General shall institute an investigation into the circumstances of the accident/serious incident and shall be responsible for conducting the investigation (Refer: Gazette of India, Registration No. D.L.:33004/99 (Downloaded from: http://dgca.nic.in/rules/1937-ind.htm)

(ii) Role / Duty of operator in assisting the investigation by Inquiry officer / Inspector of Accident / Committee of inquiry / Court of Inquiry DOACG shall assist in the investigation by Inquiry Officer. Any records and technical data as required by inquiry officer shall be made available to the inquiry officer.

1.17.2.3 Chapter 5 of Flight Safety Manual

This chapter provides procedure for Accident Prevention Program. Some of the relevant para is appended below: -

<u>Safety Awareness</u>

Imparting safety awareness amongst the personnel of an organisation is an important step for enhancing safety in aviation. Sustained education of these personnel will go a long way in achieving this objective. The Safety Awareness Programme of an operator should have the following minimum features:

(a) All flight crew, maintenance engineers, cabin crew and other key personnel shall be given periodical refresher courses to update their knowledge.
(b) The operator shall organise periodic safety seminars for the benefit of their personnel. Specialists in the field of safety may be invited to give presentations so that lessons could be learnt from the experience of others. Pilots, engineers and safety managers of the operators should participate in the safety seminars organised by the DGCA and other agencies in the country and abroad.
(c) Appropriate safety posters should be developed and displayed at different work places.

(d) Safety bulletins highlighting case studies and safety lessons from serious occurrences in aviation industry in India and abroad may be prepared and circulated to the concerned personnel.

Reactive Programme

Investigation of accidents/incidents brings out the deficiencies which have contributed to occurrences. Appropriate safety measures could prevent similar occurrences. Thorough investigation of the accidents/incidents is very essential not only to determine what happened but also to find out why it happened. Organisational deficiencies and weakness in the systems and policies shall be investigated.

The DOACG have a Permanent Investigation Board to promptly investigate the occurrences and possibly within six weeks of its occurrence to determine the cause of the occurrence and weaknesses, if any, in the above areas which are contributory factors to the occurrences. The DOACG will ensure quick implementation of the safety recommendations made by the Courts of Inquiry, Committees of Inquiry, Inspector of Accidents, Safety Audit, Spot Checks, Permanent Investigation Boards etc. The Flight Safety Department of the DOACG shall periodically review the implementation of the recommendations. The DOACG may issue Safety Bulletins on important safety aspects highlighted in an accident/incident involving an Indian or foreign aircraft.

Proactive Programme

The proactive programme is aimed to detect the weak areas in the system through various measures as mentioned below. To recognise weaknesses in a system or organisation and to take corrective measures are the key factors to ensure safety in aviation.

Following salient measures shall form part of proactive programme :-

(a) Building safety culture in the organisation and declare their firm commitment to safety
(b) The DOACG shall carry out periodically their internal safety audit of different divisions like operations, maintenance, commercial, security, ground support, etc. This shall be carried out by a dedicated group comprising of at least a senior pilot and an engineer.
(c) Periodic monitoring of CVR and DFDR must be carried out
(d) The recorded data can be analysed for the purpose of checking deviations in flight parameters beyond acceptable limits which are critical to flight safety.
(e) The crew shall be given assurance that their safety related decisions (e.g. go around, diversion, etc.) shall be supported by the management.
(f) The critical operational areas shall be monitored closely so that these do not result in any serious safety hazard. Such areas are initial induction of new pilots, transition to a totally new type of aircraft like glass cockpit aircraft, operations to and from marginal runways, operations during monsoon, loading of aircraft under high ambient temperature and elevation conditions, operations to airfields located in mountainous terrain, airworthiness and operational control of leased aircraft, etc.
(g) Flight and Duty Time Limitations shall be laid down for the operating crew to ensure that the crew are not fatigued which may affect safety of operations.
(h) Regular checks shall be carried out by the DOACG to ensure that standard weights of crew and passengers are being used and loading of aircraft is within the limits with proper center of

gravity. Load and trim sheets shall also be checked periodically to ensure their accuracy and their proper filling up for any irregularity.

(i) Periodic inspection shall be carried out to ensure adherence to apron discipline and procedures by ground support personnel, serviceability of ground support equipment and other facilities.

(j) Periodic review of emergency response procedure shall be carried out to ensure the preparedness.

As on date of accident, no safety awareness programme was conducted by the organization. However, safety meetings are being conducted in the organisation. The details of number of personnel attended the meeting is not provided in the meeting details. The last meeting before the accident was conducted on 01 Feb 2022. Further, some safety bulletins have been issued with the last one issued on 08.03.2021 prior to the accident.

1.17.2.4 Chapter 6 of Flight Safety Manual

This chapter provides procedure for Flight Operation Quality Assurance (FOQA). Some of the relevant para is appended below: -

A. Monitoring of DFDR (Agusta 109E) Model FA2300

………

(i) Procedure for monitoring exceedance trend monitoring

DoA,CG has outsourced for monitoring of FDR parameter exceedance to M/s Nest Avionics, Bangalore. Certifying staff shall download the raw data and the raw data shall be sent to the M/s Nest Avionics, Bangalore for further data conversation, analysis, monitoring of FDR parameter exceedance. The M/s Nest Avionics, Bangalore sends FDR Readout Certificate, FDR Graphical Report, FDR parameter exceedance Report to CAM. The CAM is custodian of FDM data. The CAM is responsible for protection of information related to FDR and should share it to concern in de-identification form. The CAM will forward this report to Flight Safety Department. The Flight Safety Department will check FDR Monitoring check list as per Performa. In case of any exceedances/abnormalities observed the matter is reported to the Chief of Flight Safety for further necessary action.

(ii) Utilization of Exceedance Monitoring Data

The purpose of Decoding and analysis of the DFDR / FDR data is to identify the hazards and system deficiencies in Aircraft operations before they may result in an accident rather than blame and punishment. The FDM is non-punitive. DOACG shall monitor DFDR/FDR data to determine deficiencies /shortcoming in the operation of Aircraft.

(iii) Exceedance limits for type of aircraft

Limiting value of parameter shall be compared from FDR Numeric Report sent by Nest. If any parameter is exceeded from the Limiting value, appropriate action shall be initiated.

Following Parameters shall be recorded and Limiting value of parameter shall be compared from FDR Numeric Report sent by Nest for exceedance:

………..
………..

(iv) ANALYSIS OF DATA AND PREPARATION OF REPORTS

M/s Nest Avionics, Bangalore/any other appropriately approved organization shall provide the readable data in soft/hard format, which shall be analysed to determine if any flight parameters had exceeded the laid down limit. For the flights in which the exceedances are detected a detailed analysis of flight shall be carried out of check whether or not the flight was handled as per the standard operating procedure. Correlation of CVR and FDR shall be carried out in such cases to find out actual cause of exceedances. The matter shall also be reported to the Chief of Flight Safety and Continuing Airworthiness Manager (CAM) for further necessary action as per annexure 04.

Only 38 DFDR parameters have been included which contains parameters related to engines, rotor speed, helicopter speed limit, altitude limit, etc. most of these parameters are engineering/maintenance related and only few parameters are related to operations.

1.17.2.5 Chapter 7 of Flight Safety Manual

This chapter provides procedure for Internal / Regulatory Safety Audit Program. Some of the relevant para is appended below: -

A. Internal Audit

…………

(iii) Procedure for Internal Audit.

The audit shall be carried out as per the Checklists of the flight safety Manual. Audit team shall prepare the Report and submit to the Chief of flight safety. The Report shall be detailed and comprehensive in nature, having referenced requirements applied as the basis for assessments. The identified deviations / nonconformity with the requirements of the relevant CAR, shall be clearly recorded.
…………

1.17.2.6 Chapter 13 of Flight Safety Manual

This chapter provides procedure for Risk Management. Some of the relevant para is appended below: -

1. Risk Management

The ability to identify hazards and assess risk associated with hazards is an important component of our continuous safety improvement process. If it is determined that a risk assessment is required, the person responsible for safety will conduct and document the process by completing the SMS FORM 2: Hazard Identification & Risk Management.

The risk-management process is as follows:

- the hazard or occurrence is identified;
- the associated risks are determined;
- the probability or severity risk rating is determined;
- risk control strategies, including timelines, are developed and a revised risk rating is determined;

- risk control strategies are implemented;
- implemented risk controls are assessed;
- when the process has been completed, the SMS file is updated with a narrative of the results; and
- The completed forms are stored in a secure location.

Risk Rating: The rating is assigned based on the risk probability and risk severity.

Risk Probability: The likelihood that an unsafe event or hazard condition might occur during course of operation. The numerical value is assigned based on the probability of occurrence.

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1.17.3 SMS Manual

The organization has formulated a SMS manual, however, it was not submitted to DGCA for approval as on date of accident. The SMS manual was submitted on 24 May 2024. The investigation team perused the SMS manual submitted to DGCA and some of the relevant procedures are appended below: -

1.17.3.1 Para 1.11 of the SMS manual stipulates Role, Safety Accountability and Responsibility of Personal Involve in SMS. Safety Responsibilities of some key personnel are appended below: -

<u>Safety Manager</u>

Safety Responsibility: In discharging these accountabilities, the SMS safety Manager is responsible for:

1. Ensure development of the processes need for the SMS and are implemented, adhered to and maintained.
2. Report to the Accountable Executive on the performance of the SMS and on any need for improvement.
3. Ensure safety promotion throughout the organization.
4. To provide current information and training to all staff on the safety management system and safety issues. To arrange training from external sources as necessary.
5. To promote effective hazard identification and reporting.
6. To communicate (two way information) regarding safety issues to all staff, contractors and stakeholders.
7. Assist in continuous improvement in the hazard identification and risk assessment processes.
8. To establish excellent working relationship with the organization’s safety functions and those that interface with it, including quality management.
9. Ensure that technical data for trends related to hazards, events and occurrences are analyzed.
10. To conduct / organize safety audits, surveys and inspections any aspect of maintenance and operation.
11. To conduct investigations of internal safety in accordance with procedures laid down in this manual.
12. To oversee the entire functioning of the safety management system in the organization. Participate in the Safety Review Board meetings and advise the members on issues related to the SMS.

Maintenance Manager:

Safety Responsibilities: - The maintenance manager is responsible for supporting effective maintenance of the aircraft fleet operated by the Directorate of Aviation Govt. of Chhattisgarh:

1. To systematically review and evaluate quality of work and inspection procedures whenever applicable technical instructions are issued to improve the standards of airworthiness and safety.
2. To arrange or organize initial training and refresher courses for the certifying staff and technical workers from time to time as necessary.
3. To exercise maintenance and safety control for the work undertaken for the maintenance of the aircraft inside the hangar.
4. To ensure maintenance of airworthiness standards while entrusting work to outside agencies.
5. He shall ensure that the maintenance personnel are using the correct tools, equipment and test apparatus for completion of task.
6. He shall ensure proper safety precaution and environment: such as lighting, adequate or space and availability of aircraft literature for the maintenance of the aircraft inside the hangar.
7. He shall carryout spot checks to ensure that all quality standards and maintenance procedures are adhered to by the all-maintenance personnel.

All Govt. of Chhattisgarh personnel:

All the Directorate of Aviation Govt. of Chhattisgarh personnel have the following safety responsibilities:

1. To comply with the relevant safety requirements and procedures outlined in:
2. The Directorate of Aviation Govt. of Chhattisgarh Safety Management System Manual (SMS).
3. Flight Safety Manual: and
4. Other authorized Manuals, Instructions and Notices;
5. To apply system safety measures as required by safety management procedures and instructions:
6. To advise the SMS Safety Manager of any safety occurrence or system failure and to identify and report any situation of potential risk or concern affecting system safety via one of the following means:
   i. Report directly to SMS safety Manager or their supervisor;
   ii. Personal meetings;

1.17.3.2 Para 2.5.10 of the SMS manual provides procedures for Safety Investigations. Some of the relevant paras are appended below: -

………….

For the investigation of accident and/or serious incidents in India the procedures manual of Aircraft Accident/ Incident investigation may be referred. For accidents, the Director General may order the investigation under Rule 71, by general or special order & appoint any person for the purpose of carrying out such investigation. Depending on the size and complexity of the investigation, nature of accident and investigation skills available, DGCA (H.Q.) may constitute appropriate groups as contained in guidelines on ICAO Doc 9756 Vol I after obtaining information from site and analyzing the preliminary information and evidences on the accident. In addition, the Director General may order the investigation of any serious incident involving an aircraft or a person associated with the maintenance and operation of aircraft, or both. All incidents shall be investigated by the permanent investigation board of the Directorate of Aviation Govt. of Chhattisgarh under supervision of Officer of the Regional Air Safety Offices.

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1.17.4 Internal Audits carried out by organisation

The organisation has developed procedures wherein they carry out internal audit of their Operations, Maintenance set-up, etc. including audit by flight safety.

1.17.4.1 CAR145/CAMO

During one of the CAR-145 internal audit carried out by the team headed by QM during the year 2021, it was observed that the helicopter was operating with tail rotor hub assembly exceeding its retirement life limit. The helicopter was flown for about 89:50 hrs with exceeded retirement life limit of tail rotor hub assembly. The tail rotor hub was subsequently replaced on 01 Feb 2021.

1.17.4.2 Flight Safety

The flight safety is required to carry out internal audit every quarter in the areas of Apron/Ramp inspection, Engineering activities, pre-flight medical, load & trim sheet, etc. The investigation team perused the reports of flight safety internal audit from 26.12.2017 to 27.12.2021 submitted by the operator and following was observed: -

- There have been no findings in any of the inspections carried out during this period.
- Despite having no findings, at times it has been observed that the audit has been closed after a gap of aprrox 03 months.
- In some of the cases it has been observed that the auditors (Crew) are auditing their own flights for load & trim, CVR monitoring, etc.
- The audits are being conducted without any proper system of distributing tasks to dedicated personnel who are qualified and trained in that particular area of inspection.

1.17.5 DGCA Audit/Surveillance of organisation.

The investigation team perused the surveillance inspection carried out by DGCA and the action taken report submitted by the operator in respect of the same. Following are the salient observations: -

- There have been findings of non-reporting of mandatory occurrences to DGCA.
- Proper analysis of FDR data for FOQA monitoring are not done.
- There were findings on SMS training and safety meetings not being carried out in the organisation as per the requirement.
- Most of the CAR-145/CAR-M surveillance findings were related to hangar, stores, log entries of tools, etc.

As on date of accident, no regulatory audit has been conducted of the organisation by DGCA.

1.17.6 Past incidents of the organisation (Fixed wing incident)

The organisation is operating one fixed wing B200 aircraft with registration VT-CTG under its AOP. On 06.12.2021, the aircraft VT-CTG was involved in an occurrence wherein the RH wing was damaged while operating flight from Raipur to Jashpur. The occurrence was investigated by DGCA and also by the operator under PIB (Permanent Investigation Board). Following are the salient preliminary observations: -

- The aircraft was planned for Raipur-Jaspur-Raipur flight on 06.12.2021. The aircraft after completing the flight landed back at Raipur at 1724 hrs IST on 06.12.2021.
- Accordingly, wildlife strike form was submitted to DGCA on 08.12.2021 declaring the damage to the right wing as "Minor Dent" due to suspected bird hit. The occurrence was reported by PIC to the CoFS of the organisation on 07.12.2021 only after 21 hours of the time of occurrence.
- The preliminary findings revealed that the operator had tried to conceal the actual cause and further investigation as categorizing the dent as "small dent" and reasoned due to bird strike. Both PIC and AME, in their capacity, had tried to avert the proper course of investigation.
- The AME had assessed the dent on RH wing LE to be beyond the acceptable limits as per the damage report.
- There was no indication of any bird hit or turbulence during the Jashpur-Raipur sector as heard from CVR.

1.18 Additional Information

1.18.1 DGCA requirement for Recurrent training (Helicopter pilots)

Para 9.3 'Recurrent Training' of CAR Section 8, Series H Part II provides requirement for recurrent training of helicopter pilots. Relevant portion of the said CAR is appended below: -

9.3 Recurrent Training

9.3.1 Flying Recurrent Training. All pilots shall undergo recurrent training at least once in two years, on a FFS Level B/C/D or FTD 6/7 (FAA Designation). Instrument Flying (only for IR pilots) and the practice of those parts of emergencies such as touchdowns in engine failure, hydraulic failure, multiple system failures, tail rotor failure/control failure, loss of tail rotor effectiveness (LTE), Vortex Ring etc which cannot be practiced in actual flying shall be carried out. All major failures of systems and associated procedures shall be covered in a period of two years.

9.3.1.1 The minimum duration of this training shall be 8:00 hrs for IR pilots. This breakdown shall be 4:00 + 4:00 hrs (IF + Emergencies) respectively.

9.3.1.2 The minimum duration of this training shall be 4:00 hrs for non IR pilots for practice of emergencies. For pilots flying SE helicopters this duration shall be 3:00 hrs.

9.3.1.3 In case a specific to type FFS Level B/C/D or FTD 6/7 (FAA Designation) is not available anywhere in the country or abroad for a particular type, recurrent training may be flown on the helicopter for the same duration as specified in Para 9.3.1.1 and 9.3.1.2, after prior approval of DGCA.

In the wake of COVID-19 pandemic, DGCA had issued an operational circular 02 of 2020 dated 08 July 2020 wherein extension was given to the crew including helicopter pilots for recurrent training. As per the circular following was applicable in respect of recurrent training for helicopter pilots: -

1. Operator requires to carry out risk assessment and mitigation as per OC 4/20.

2. Use of distance learning/classroom training to provide a refresher on knowledge and SOPs including normal and nonnormal operations as per syllabus for Modules I to IV at Para 9.3.2 of CAR 8/H/II with a TRE/TRI.

3. Training on aircraft shall be as per following details for an extension upto 12 months: -

- Single Engine pilots to do a minimum of 01:30 hour of recurrent flying training with a TRE/TRI.
- Multi Engine crew to do 04 hours (02h Critical Emergency Trg and 02h IF Trg) on aircraft with a TRE/TRI.

It was mentioned that the stipulated extensions are valid till 30th Sept. 2020 or until revocation of this OC, whichever is earlier.

The above-mentioned relaxation was further extended vide DGCA e-mail dated 08 January 2021 sent to helicopter operators.

1.18.2 DGCA CAR requirement for Flight Safety Awareness and Accident/Incident Prevention Programme

DGCA CAR Section 5, Series F, Part 1 dated 28.06.1996 (Rev 2, 17 March 2009) provides requirement for operators to have a Flight Safety Awareness and Accident/ Incident Prevention Programme to enhance the safety of aircraft operations. It is mentioned that this Civil Aviation Requirement is applicable to all operators engaged in scheduled air transport services / Cargo Services/ non-scheduled air transport services. However, there is no mention of other operators such as State Government, Private and other General Aviation operators. Hence, it is not clear whether the requirements under this section are also applicable to these organisations.

1.18.3 DGCA CAR requirement for FDAP (Flight Data Analysis Program) for helicopters

DGCA CAR Section 5, Series F, Part II dated 25.01.2022 provides requirement for operators having aircraft equipped with FDR. Relevant portion of the said CAR is appended below: -

Para 2.3 of CAR: Scheduled / Non-Scheduled operators of helicopter with certified take-off mass in excess of 7000 kgs or having a passenger seating configuration of more than nine and engaged in onshore/ inland operations shall monitor and analyze one FDR for each helicopter per quarter.

Para 3.2 of CAR: Ground facilities for decoding and analysis:

a. An operator should develop a facility to acquire the data, analyze and identify deviations from expected performance.

b. All scheduled operators as in para 2.1 shall have software for flight animation facilitating a visual simulation of actual flight events. Others are encouraged to develop such facility.

c. An operator may contract the operation of flight data analysis programme to another party while retaining overall responsibility for the maintenance of such a programme.

Para 3.3 of CAR: Specific procedures for data removal should be defined for maintenance personnel to minimize the loss of data.

Para 6 of CAR: Analysis of Data & Preparation of Reports

6.1 Entire data of a flight shall be analyzed to determine if any flight parameter had exceeded the laid down limit. If any exceedance is detected appropriate report for the same shall be generated in the format given in the Annexure 'C', giving the actual value of the parameter, the specified limit for the same, the time of the event and the other relevant flight details.

6.2 For the flights in which the exceedances are detected, a detailed analysis of flight shall be carried out to check whether the flight was handled as per the Standard Operating Procedures. As there are more accidents during approach and landing phases, detailed analysis of the approach and landing phases of all flights shall be carried out, to detect any deviations from the normal approach profile and whether the approach was stabilized or not.

6.3 Data relating to landings should be analyzed for airports, runways, heliport and helipad.

1.19 Useful or Effective Investigation Techniques

NIL

2. ANALYSIS

2.1 Serviceability of the Aircraft

2.1.1 General

The helicopter was manufactured in the year 2007. The helicopter was having a valid Certificate of Registration (C of R) at the time of accident. It was holding a Certificate of Airworthiness (C of A) which was valid for lifetime subject to validity of Airworthiness Review Certificate (ARC). The ARC was valid at the time of accident. The helicopter had logged 3343:55 Airframe hours/6776 cycles till the day of accident. The last scheduled inspection carried out was 50 Hrs./30 days inspection on 01 May 2022 at 3331 A/F hours. There was no snag reported by the pilot before the accident flight. Scrutiny of the Technical Log Book revealed that there was no reported snag pending on the helicopter prior to this accident.

2.1.2 Maintenance/inspection carried out on the aircraft

The helicopter has been maintained as per extended inspection program as per Maintenance Planning Manual (MPM) which was also approved by DGCA. The scheduled inspections consist of 50 hrs/30 days, 200 hrs, 400 hrs, 800 hrs, 3200 hrs and 12 months inspection. Apart from this there are some unscheduled special inspections which is required to be carried out.

Based on the available evidences like ATC tape, statements of various personnel, etc. it was evident that the crew announced priority landing due to loss of tail rotor effectiveness. After the accident the tail rotor assembly along with blades, TGB, etc. were retrieved from the helicopter wreckage for further detailed examination. During the detailed examination of tail rotor assembly components at LH facility following was observed: -

- The inspection on the tail rotor parts revealed the loss of the tail rotor pitch control in flight.

- The locking nut came off the support bearing sleeve assembly with the consequent duplex bearing disassembly, which caused furtherly the loss of connection between the slider assembly and the support bearing.
- The outboard locking nut did not tear the support bearing thread, which remained overall intact, but unscrewed from it.
- The unscrewing of the locking nut was likely due to a loss of tightening torque which allowed it to move in the vibratory environment and above all favoring the progressive failure of the locking wires. However, the locking wires were not available for investigation, hence, no evaluation could be made regarding their condition, installation and possible failure.
- There is a possibility that the tightening torque was applied low while installing the locking nut, or it may have decreased progressively in flight, but in either case it is highly probable that it is a result of poor maintenance tasks accomplishment.
- The poor maintenance task is further evident from the following: -
  - Significant evidence of this is the absence of the thread locking adhesive (Loctite® 222) to be applied between the mating threads of the support bearing and the locking nut, as required by the maintenance manual.
  - The washer to be fitted under the locking nut of the special hub plug (mating to the balancing flange) in accordance with the maintenance manual, was not installed;
  - The washer to be fitted to both the hub flange assemblies in accordance with the maintenance manual was not installed on the outboard side. Instead of the required washer, two thinner and smaller in diameter washers were installed;
  - The shims installed under the two hub flange assemblies have a different thickness, while the maintenance manual requires them to be equal;
  - The disassembly of the half scissors connecting the slider assembly to the sleeve assembly revealed the application of a tightening torque to the nuts not indicated in the maintenance manual, which only provides for their gentle tightening up to the elimination of the axial play of the links. Furthermore, the extracted bolts showed a considerable wear damage, with great alteration of their geometry due to the material loss;
  - The inner bushing of the slider shows a heavily worn lining with a small area of exposed underlying web. Furthermore, the bushing was found detached from the slider inner surface. The maintenance manual requires inspecting all tail rotor parts for any evidence of damage or corrosion and in particular to check the bushing lining for wear and to replace the bushing if the underlying web becomes visible;
  - The outboard locking nut is almost completely brown in color due to generalized oxidation resulting from the loss of the protective cadmium plating required by the drawing. Furthermore, the thread and the bearing seat of the support bearing almost completely lost the chromate conversion treatment required by the drawing. The maintenance manual provides for inspecting all tail rotor parts for any evidence of damage or corrosion.

The scrutiny of the maintenance documents revealed that the last major inspection which required removal of tail rotor assembly including disassembly and reassembly of the Tail Rotor Pitch Change Mechanism carried out was 400 hrs scheduled maintenance. The task was carried out on 20.10.2020 at 3024:05 A/F hours. The maintenance task requires removal of tail rotor hub assembly and detailed inspection of respective components for its condition, wear, etc. It is evident from the above findings that the task was not carried out properly as per the laid down procedures during this scheduled maintenance.

After this scheduled maintenance of 400 hours there were number of other scheduled/unscheduled maintenance inspections carried out on the helicopter which required inspection of tail rotor area. The 200 hours schedule maintenance which requires removal of tail rotor was carried out on 31.08.2021 at 3209 A/F hours, i.e., 134 flying hours before the accident. The 50 hrs/30 days scheduled inspection also requires visual inspection of tail rotor pitch change mechanism for condition, security and unusual play. The last 50hrs/30 days inspection was carried out on 01.05.2022 at 3331 A/F hrs i.e., 10 days prior to the accident and the helicopter had flown for about 12 hours since then. It further reflects that these subsequent inspections (including the visual inspections) were also not carried out properly as per the laid down procedures.

In view of the above findings, it is evident that the helicopter was not maintained properly as per the laid down procedures prescribed in the maintenance manual. Even proper visual inspection could have identified any discrepancy in the tail rotor assembly. The non-adherence to the laid down procedures during the various maintenance task led to the loss of tail rotor pitch control in flight. The serviceability of the helicopter due to poor maintenance contributed to the accident.

2.2 Flight recorder (CVDR) data analysis

The helicopter was fitted with combined CVDR flight recorders. The data was retrieved from the recorders and was analysed with the help of ANSV, Italy and Leonardo Helicopters.

The CVR and FDR data was analysed and following are the sequence of events of the accident flight: -

- The aircraft took-off from Raipur airport at around 1457 UTC.
- Initially, the helicopter was flown by the co-pilot (Pilot flying) and after about 10 minutes of flight, the co-pilot felt that there is some problem with the tail rotor effectiveness. The co-pilot informs the same to the PIC. The same is consistent with the FDR parameters wherein evidence of loss of tail rotor control was observed at 1505 UTC, where small periodic uncommanded attitude variation on the Pitch and Roll axis (max 2.5° pitch, 7° roll) was observed. At this time the helicopter was flying at 3540 ft AMSL and 132 KIAS.
- The co-pilot thereafter asked PIC to check if the same is confirmed. The PIC also felt the problem. They then decided to land back at Raipur. The co-pilot informs ATC that they will return back due technical and reported their position as 20 Nm from Raipur. The co-pilot also informs that they are maintaining 3100 feet. From that point onwards the controls were with the PIC, however, no handing over/taking over controls call out were made by the crew as per the procedure.
- The Crew initially reacted to the emergency in accordance with the relevant RFM procedures. PIC controlled the A/C attitude changes with Cyclic inputs and the Tail Rotor Pedal authority was checked immediately, in order to properly identify the issue. Torque demand was managed with progressive and slow actions of the collective, in order to both achieve a reduction in the need for anti-torque and maintain the current heading with only minimal cyclic inputs.
- The crew thereafter were discussing that the tail rotor control is intermittent i.e., in between they are able to feel the tail rotor effectiveness while applying continuous left pedal. This was

also consistent with FDR data wherein it was observed that the Pedal recording shows a repetitive and progressive Left drift, reaching 100% over several minutes, before it was repetitively re-centred manually.

- From the loss of tail rotor control onwards, the PIC was likely flying hands-on and acting on the Force Trim release switch in order to maintain heading.
- The PIC told co-pilot that they need to check the effectiveness of the tail rotor i.e., upto what speed the heading can be maintained and also calls out that other than this all other parameters are normal. Accordingly, they checked the effectiveness by reducing the speed. The co-pilot calls out that upto 50 knots they are able to manage the heading, however, the PIC said they need to check this in descent as they have done it in level flight only.
- The PIC told co-pilot that they need to declare the priority as they will not be able to vacate the runway and it may be blocked. The PIC then asked co-pilot if they can call the chief pilot and ask them to bring towing arm to the airport.
- The co-pilot tried calling the chief pilot but could not connect as there was no mobile network. The PIC then told co-pilot that they will do one overshoot (low pass) over runway to check the tail rotor effectiveness and then try to land after that.
- The co-pilot accordingly informs ATC that they will carry out an overshoot over runway first and then they will land. The ATC gave the approval. The co-pilot then informs ATC that there may be a problem in vacating the runway and asked ATC to call the chief pilot for towing arm.
- The crew were then discussing about the tail rotor effectiveness. PIC told co-pilot that in between right rudder is effective, but in order to land they need left rudder which is not responding. The PIC further said they have to refer checklist and they have taken all the actions as per the checklist. PIC further added that by lower speed checks along the runway they will know upto what speed and which direction the helicopter is maintaining.
- The co-pilot was reading the RFM procedures and said that in case of total loss then they have to land/touchdown and switch off the power. The PIC responded by saying that there is no total loss as there is no sound of tail rotor and no violent rotation with reduction in speed. PIC further told co-pilot that in any case they are overshooting and at that time they will check. The co-pilot then asked PIC regarding upto what speed they will reduce for which the PIC said they will see during overshoot at what speed it is maintaining.
- The co-pilot then calls the chief pilot over phone to appraise him about the situation and asked to arrange for towing arm.
- The PIC then asked the co-pilot if there is any action left as per the procedure. Then both the crew discussed the RFM emergency procedure.
- The co-pilot then informs ATC that the runway is in sight and they will carry out a low pass to adjust the speed for landing. ATC clears the helicopter to land on runway 24 and informs winds as 200°/04 knots.
- The PIC initiated the approach and the co-pilot was calling out the height and ground speed. They descended to about 240 feet AGL and ground speed was reduced to about 40 knots as called out by the co-pilot. The PIC then said that we can land with 40 knots as we have come to ground effect now. The co-pilot said we will go around and let that aircraft to depart. There was a scheduled aircraft ready for departure at Raipur.
- The PIC said we will come close to the ground or we can land also in this approach itself. The co-pilot said we can land but we will not be able to clear the runway. The PIC then asked if the

towing arm will be available by that time for which the co-pilot was not sure if it will be available. However, the co-pilot informs ATC that they are totally comfortable now and will make approach landing in this approach itself.

- The co-pilot, however, calls out to PIC that we will go around and allow that aircraft to take-off then we will land at the beginning of runway. The PIC also agrees to it. Accordingly, co-pilot informs ATC that they will go around and allow the aircraft (on ground) to depart then they will land at beginning of runway. The crew subsequently carried out a go around. This also corresponds to the FDR data wherein it was noticed that at approximately 15:26 UTC, the data indicates a manoeuvre corresponding to a possible first landing attempt on RWY 24 at VERP, as the IAS was progressively reduced to 40 KIAS while the helicopter was steadily descending with 240° magnetic heading. Further, the helicopter attained an altitude of 2000 to 2100 ft AMSL.
- The crew again started discussing about tail rotor ineffectiveness wherein co-pilot asked PIC that if the helicopter is able to turn to the left. However, the PIC tells co-pilot that the rudder is stuck at one place (about 40 to 50 knots) and it is ineffective.
- Crew then decides that they will let the two scheduled aircraft to depart first and then will land in case the helicopter hold up on runway. Co-pilot accordingly informs ATC.
- The ATC asked the crew to make orbit left downwind for which the Co-pilot said we will make loose flight due to less rudder control. However, the PIC told co-pilot that there is no problem in carrying out orbit and said that it is when the helicopter comes close to the ground (under ground-effect) with lower speed then it has the tendency to go to the right. Hence, the PIC asked co-pilot to keep reminding to maintain the speed.
- During further discussion about procedure to land, the co-pilot asked PIC if they will not lower the collective? For which the PIC said no they will lower the collective.
- ATC then asked crew to inform the endurance for which the co-pilot informed they have 01 hour endurance.
- PIC then told co-pilot that all actions that are required to be taken is complete. They are maintaining speed and will be consuming fuel so that the helicopter becomes light and in the meantime the aircraft (on ground) can also depart.
- The PIC again tells co-pilot that they will maintain a speed of 60 knots and reduce towards the end to get the nose straight.
- ATC informs that one aircraft is ready for taxi and another will get ready in 20-25 minutes. The crew decided that after the departure of the aircraft which is ready for taxi they will land. The same was informed to the ATC.
- The co-pilot continued the discussion for landing procedures and PIC said that they will apply brakes and control the direction with brakes. If there is no direction control with the rudder, they need to control the direction by brakes. PIC also tells that it is possible to taxi with the help of brakes but they will see after landing.
- The co-pilot again started discussing about landing techniques, about reduction of collective, its torque demand, etc. The PIC told co-pilot that they will keep braking and keep reducing the collective.
- The crew were making orbit during this time and they waited for the other aircraft (on ground) to depart after which they positioned the helicopter for finals. This was also consistent with FDR data where it was observed that the crew performed at least four full 360° orbits and all while the PIC maintained full control on the speed and attitudes of the helicopter.

- The crew carried out approach to land on runway 24, the PIC informs co-pilot that there is no problem with the power.
- ATC then gave landing clearance to the helicopter and informs winds as 170°/05 Kts. The co-pilot was calling out altitude and speed. Subsequently, at 200 feet, speed 57 knots callout was given by the co-pilot. Thereafter, auto call out of 150 was heard in the cockpit.
- The co-pilot then calls out 100 feet with speed 57 knots and after 08 seconds PIC asked co-pilot to inform ATC that they will go around. The same was communicated to ATC by co-pilot. This was also consistent with the FDR data which indicates the behaviour of the helicopter same as that for earlier go around.
- The PIC said that the speed got reduced that is why go around was initiated and asked co-pilot to keep reminding not to reduce the speed.
- ATC then asked the intention for which the co-pilot replied they will land on this approach.
- The co-pilot then calls out “80 knots, 640 feet” for which the PIC said it has not reached 80 Knots indicated speed yet, it is the ground speed which is 80 knots and they need indicated air speed. The co-pilot affirms the same.
- The ATC again gave landing clearance for runway 24 with winds 160°/05 knots.
- The co-pilot calls out we are “60 knots, 350 feet”. The PIC said I am giving the ROD now.
- The co-pilot calls out “60” …simultaneously auto call out of 150 is heard in the cockpit. Co-pilot again calls out 60 knots at 100 feet and keeps on calling the speed. Thereafter, the helicopter touched down. This was consistent with the FDR when the helicopter touched down at 15:46:57 UTC (T = 699925 seconds DFDR reference time) with WOW (Weight on Wheels) active and IAS of 52 knots.
- Immediately after touchdown the PIC was heard saying “Apply brakes apply brakes” to which the co-pilot replies by saying “sir”. The PIC again calls out “apply brakes”. This was also consistent with the IAS trend, which showed a slow deceleration (from 52kts at WOW=ON to 38kts 12s later) and a minimal RH yaw (8° in 13s, up to 247° magnetic). This indicates a lack of action by the Crew on either the Toe Brakes or the Emergency Brake lever, which would have resulted in a faster deceleration.
- The PIC then calls out “its ok..its ok let it go.. it will go to the right little bit”. This was also consistent with the FDR data that the magnetic heading of helicopter after touchdown changed upto 247°.
- Further, during the helicopter rolling on runway, the PIC was heard saying “No…No….No…don’t” for which the co-pilot said ‘OK’. As per FDR data for at least 13s the helicopter rolled down RWY 24, with the PIC applying almost full AFT Longitudinal Cyclic (10%) and keeping the Lateral stick neutral (except for a short LH correction ~8s into the landing). Collective had been moved to MPOG and consequently Torque demand was minimal (18%), while both Engines were kept in FLT mode.
- During this period in the cockpit, it appeared that the PIC was trying hard to bring the helicopter nose back to runway heading. Suddenly, the co-pilot was heard calling out “Ok collective” and pulled the collective. This was consistent with FDR data wherein at 1547 UTC, an abrupt Collective pull was recorded (from MPOG to 68.7% in less than 2s). The PARK BRAKE ON caution was also activated which was probably done by the PIC who was occupying the left seat.
- Thereafter both Engines immediately responded reaching to 90-92% TQ, and the helicopter initiated a sharp RH turn and lifted off again 1s later.

- From this point in time onwards the Flight Path data shows a behaviour consistent with a complete lack of control of the helicopter, with at least 7-8 full 360° RH rotations with a yaw rate reaching above 360deg/s. The helicopter climbed up to 1680ft AMSL before descending again while spinning CW. This is also consistent with the CVR, where sounds of helicopter rotating with various alarms like "rolling…rolling" was heard inside the cockpit and the helicopter subsequently impacted the ground.

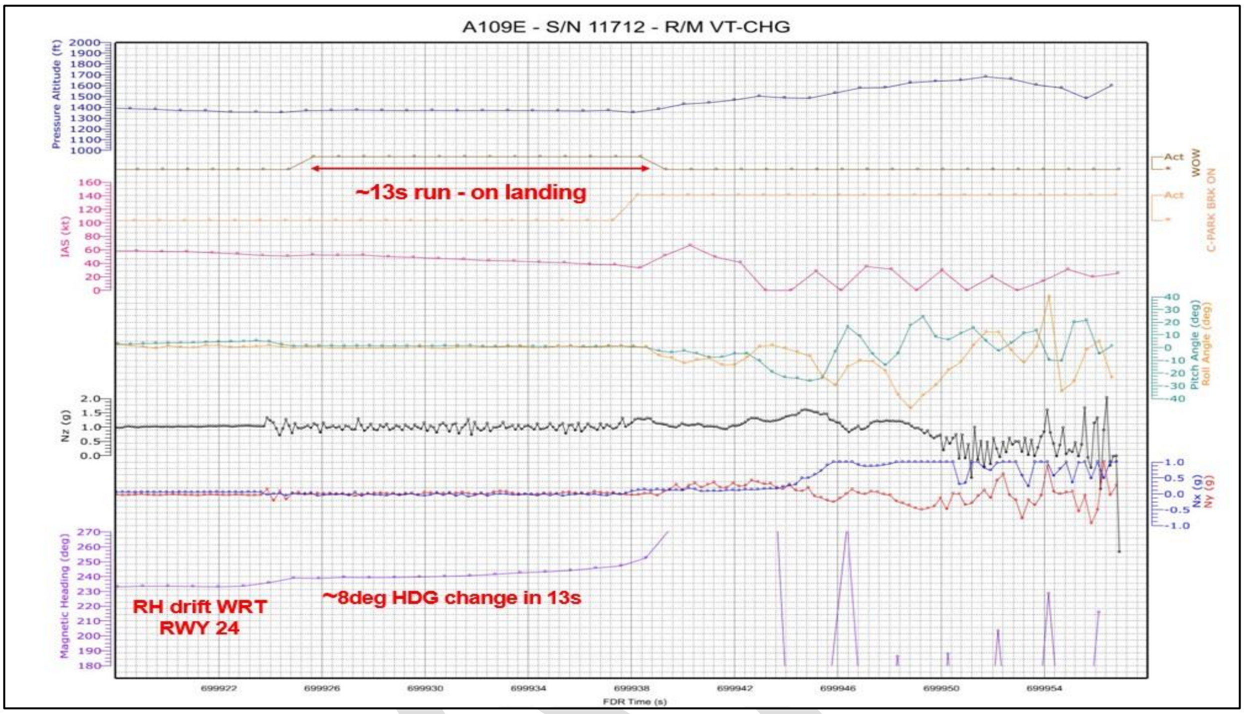


Fig 17: Graphical representation of parameters vs FDR time during final phase (Part 1)

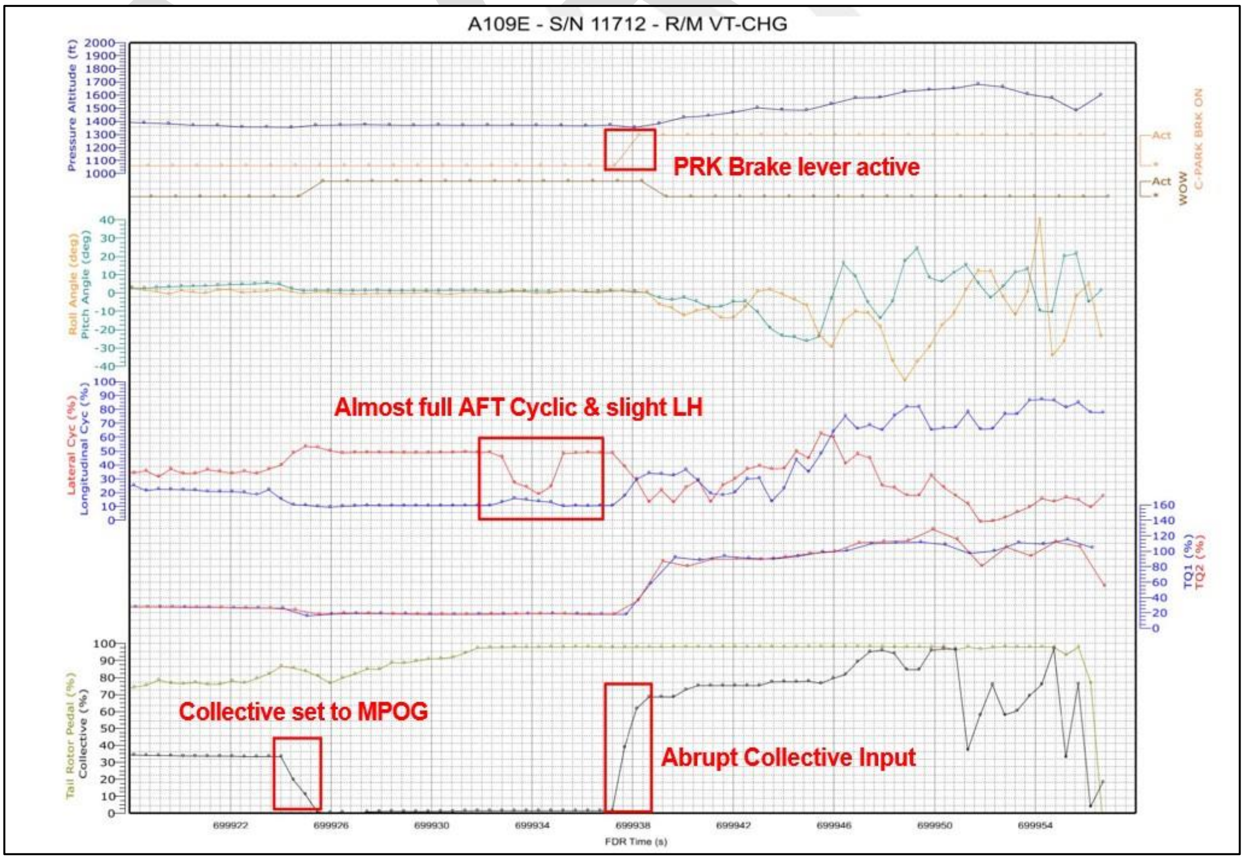


Fig 18: Graphical representation of parameters vs FDR time during final phase (Part 2)

2.3 Crew qualification and handling of emergency

2.3.1 Crew Qualification

Both the operating crew were qualified pilots on type. They both had valid licenses as on date of accident. They both were designated DGCA examiner on type.

The PIC was a CPL(H) holder qualified on type and had a total flying experience of about 9456 hours including about 2321 hours on type. PIC held all the required training/medical for operating the flight and were valid as on date of accident.

The co-pilot was a senior pilot in the organisation. Co-pilot was also a CPL(H) holder. Co-pilot held all the trainings / medical examination as per the requirements and were current as on date of accident for conduct of this flight. The co-pilot had about 6189 hrs of total flying experience including 2014 hrs as PIC on type which indicates that most of the PIC flying was carried out on Agusta A109E helicopter.

Both the crew were qualified to operate the flight on 12 May 2022.

2.3.2 Crew Co-ordination and handling of emergency

Initially the helicopter was flown by the co-pilot (company pilot) occupying the right seat as this was his night flying check with a DGCA examiner as PIC occupying the left seat. After the tail rotor ineffectiveness was detected by the co-pilot, the PIC thereafter started flying the helicopter as evident from the conversation in the cockpit thereon. However, there was no call out made by the crew regarding "Handing Over/Taking Over controls" as per the laid down procedures. Despite not calling out for changeover of controls, the crew did not panic and there was no conflict regarding operation of controls at that time. They discussed the situation and carried out the actions to identify the problem.

The crew did not carry out landing immediately after detecting the problem, instead decided to carry out a low pass over runway to ascertain the minimum speed upto which the helicopter is maintaining heading. The co-ordination between the crew was fine till the time crew carried out a low pass over runway. The low pass was communicated to the ATC and accordingly ATC gave clearance to the helicopter. During the approach there was evidence of lack of co-ordination wherein PIC told co-pilot that the helicopter is controllable and can land the helicopter in this approach itself. The crew were not sure about availability of tow bar; however, the co-pilot agrees and informs the ATC that they will make approach landing during this approach itself. However, while coming close to the ground, the co-pilot tells PIC to go around and let the other aircraft (waiting on ground for departure) to depart first as there was possibility of helicopter blocking the runway. The co-pilot immediately informs ATC and they carry out a go around. They then decided to land after the departure of two aircraft scheduled for departure.

The crew discussed the tail rotor ineffectiveness/rudder ineffectiveness in detail; however, they took considerable time to refer the RFM procedures for carry out landing in such situation.

Further, from the conversation between the crew, it appeared that the co-pilot was not fully aware of the situation i.e., about the behaviour of the helicopter in such condition. This was evident from the number of discussions the co-pilot had with PIC regarding behaviour of the helicopter after tail rotor ineffectiveness. One such instance was when the ATC asked the crew to orbit after the low pass for which the co-pilot informs ATC that they will not be able to orbit due to less tail rotor effectiveness. The PIC however told co-pilot that there will be no problem in carrying out orbit as the problem exists when the helicopter comes to the ground effect at low speed. The PIC, however, seemed to be confident and aware of the situation. The PIC maintained the helicopter heading by using the other controls. Further, during the orbits also, the co-pilot had number of discussions with PIC regarding procedure for landing in such condition such as if lowering of collective is required, torque demands during landing, etc. The PIC replied that they will keep braking and keep lowering the collective. In spite of not being fully aware of the situation, the co-pilot followed the PICs instructions throughout the flight until the landing roll.

During the second approach to land while the PIC was still flying the helicopter, the co-pilot was calling out the ground speed and height. The helicopter descended below 100 feet after which the PIC asked co-pilot to inform ATC that they will go around. The PIC aborted the landing and carried out go-around. As per the PIC the speed got reduced below required for landing (60 knots IAS) in such condition. The PIC further asked co-pilot to keep reminding not to reduce the speed.

During the third approach for landing, the co-pilot calls out “80 knots and height 640 feet”. The PIC then tells co-pilot that the helicopter did not attain 80 knots indicated speed yet and the co-pilot was calling out ground speed rather than indicated air speed which is required for landing in such condition. Thereafter, the co-pilot started calling out indicated air speed. The lack of co-ordination was further evident during landing, when after touch down, the co-pilot did not apply brakes and PIC was calling out to co-pilot “apply brakes”. Further, during the landing roll, the PIC was heard saying “its ok its ok let it go, the helicopter will go to the right little bit” and subsequently the PIC was heard saying “No…No…No…don’t…” which probably reflects that the PIC was trying to stop co-pilot from executing an action which the PIC felt was not supposed to be done in such situation. Further into the landing roll, the PIC was trying hard to bring the helicopter nose straight into runway heading during which the co-pilot suddenly calls out “ok collective” and pulls the collective (the collective was pulled from MPOG to 68.7% in less than 2 seconds). At the same time the PIC probably applied parking brakes as “Parking brake ON” caution was also activated. Immediately after the collective was pulled the helicopter lifted up and thereafter lost control. With the available data there was no specific reason of this sudden application of torque demand by the Crew, as no anomaly was detected during the running landing and the available CCTV footage did not hint presence of any obstacles on the runway or to an impending excursion.

In view of the above, it is most probable that the co-pilot was not fully aware of the emergency situation and handling of the aircraft in such situation. Further, due to the loss of situational awareness and observing that the helicopter was not able to maintain the direction, the co-pilot probably panicked and pulled the collective without realising the fact that the tail rotor is ineffective.

Apart from this, there was evidence of lack of co-ordination and application of CRM procedures between the crew especially during the critical phases of flight. This lack of co-ordination may be attributed to the fact that both the crew were DGCA examiners with good amount of flying experience on type. This probably led to a situation where they presumed that the other member will be knowing what actions are required to be carried out in such situation without actually sharing the tasks between them to avoid any conflict. This lack of co-ordination led to inactions of various tasks (in accordance with RFM procedures) during critical phases of flight which resulted in 02 aborted landings before the helicopter touched down during the third approach wherein the lack of co-ordination was more evident. The crew took considerable time to refer the RFM emergency procedures for tail rotor ineffectiveness. However, despite going through the RFM emergency procedures during the flight, the crew did not adhere to these procedures while landing the helicopter. The crew landed the helicopter with engines in FLT mode rather than putting it on idle or even switch OFF as suggested by the RFM procedures for this particular situation. Lack of application of brakes after touchdown further aggravated the situation. Lack of understanding of the emergency situation on the part of co-pilot also contributed to the crew co-ordination problem during critical phases of flight.

The lack of crew co-ordination (CRM) and Non-adherence to the RFM procedures led to the accident.

2.4 Organisational Aspect

2.4.1 Aircraft Maintenance

The organisation has its own maintenance set-up under CAR-145 approved by DGCA. The accident helicopter VT-CHG and the fixed wing B200 aircraft VT-CTG were being maintained by the organisation themselves.

Apart from observations made during the detailed examination of tail rotor assembly components which brought out that the helicopter VT-CHG was not maintained as per the laid down MM procedures, there were many other maintenance and procedural lapses found during the course of investigation which are discussed below: -

- The scheduled inspection of 50 hours/30 days were not carried out as and when due. On many occasions it was observed that there was delay in carrying out these inspections.
- The Scrutiny of maintenance and other documents such as technical log book, CRS book, work package of inspection and tasks, etc. revealed poor documentation practice. Some of findings are as follows: -
  - Technical logbook: - The information such as part number of component replaced are not mentioned. For a period of three months, the information regarding next inspection due was repetitively mentioned as 25 hrs special inspection rather than recording the actual scheduled/unscheduled maintenance due next. In the pilot acceptance column, the pilots are appending only their signatures without putting their license number as per the requirement. The procedure specified in operations manual says that after acceptance by the pilot, out of the three sheets (01 original and 02 duplicate) one of the duplicate copies will be kept with the engineering for record purpose before the flight. The engineering department kept a file of these techlog pages of pilot acceptance. In most of these pages there was no mention of name of the pilot.
  - Certificate of Release to Service (CRS):- Scrutiny of the CRS booklet revealed that CRS for some of the scheduled/unscheduled maintenance inspections including that of SB compliance was not available in the records.

- Work Package: - Scrutiny of work package of various scheduled maintenance provided to the investigation team revealed that the CRS for some of the maintenance tasks was not available in records. Further, in some of the schedule no entry was made for special tools used during the maintenance task.
- Log book: There have been lot of cuttings and correction made on entries made in the log book.
- Log cards: As in case of log books, there were lot of cuttings in the entries made in the log cards as well. Further, after an overhaul of a component in most of the entries made under time since overhaul it is mentioned as 'NEW' rather than 00:00 hrs.
- The log card in respect of tail rotor hub assembly does not contain details of its various components. The tail rotor hub was replaced on 01 Feb 2021.

It is evident from the above findings that the maintenance documents are not being maintained properly as per the laid down procedures.

➢ During one of the internal audits carried out in the organisation, it was observed that the helicopter VT-CHG was operating with tail rotor hub assembly exceeding its retirement life limit. After this observation, the tail rotor hub was replaced on 01 February 2021. The helicopter was flown for about 89:50 hrs with the exceeded retirement life limit of tail rotor hub assembly.

In view of the above, it is evident that the practice of poor maintenance has been existing in the organisation. Apart from poor maintenance practices, there is no proper updation of records. With the fact that the helicopter was being flown with a component which had exceeded the retirement life implies that there is no system in place to identify the components which are due for replacement/repair. Further, the poor maintenance of the only helicopter under its AOP reflects lack of safety culture within the maintenance set-up of the organisation.

2.4.2 Reporting of Occurrences

The various manuals formulated by the organisation such as Operations Manual, flight safety manual, SMS manual provides requirement of notifying mandatory reportable occurrences to DGCA as per relevant Rules/requirements laid down in this regard.

The organisation is operating one fixed wing B200 aircraft with registration VT-CTG under its AOP. On 06.12.2021, the aircraft was planned for Raipur-Jashpur-Raipur flight. The aircraft after completing the flight landed back at Raipur at 1724 hrs IST on 06.12.2021. The aircraft VT-CTG was involved in an occurrence during the Raipur to Jashpur flight wherein the RH wing was damaged. The occurrence was reported by PIC on 07.12.2021 to the CoFS of the organisation only after 21 hours of the occurrence. Wildlife strike form was submitted to DGCA on 08.12.2021 declaring the damage to the right wing as "Minor Dent" due to suspected bird hit. During the preliminary investigation by DGCA, it was observed that the operator had tried to conceal the actual cause and categorized the dent as "small dent due to bird strike". Both PIC and AME, in their capacity, had tried to avert the proper course of investigation. During the course of preliminary investigation conducted by DGCA, the dent on the RH wing was found to be beyond the acceptable limits. Further, CVR replay revealed no indication of any bird hit or turbulence during the Jashpur-Raipur sector as initially reported by the organisation. It was further revealed that the incident occurred during the Raipur-Jashpur flight and the return flight to Raipur was flown with the damaged wing. Apart from this various other safety lapses were observed.

DGCA during their flight safety surveillance of the organisation have also made findings regarding non-reporting of occurrences. This reflects existence of poor reporting system in the organisation. The crew along with the maintenance personnel concealing the facts after such an incident also indicates that the required safety standards are not being met.

2.4.3 Flight Safety Set-up

2.4.3.1 Safety Internal Audit

The organisation has a flight safety set-up as required by relevant DGCA CAR in this regard. The flight safety is required to carry out internal audit every quarter in the areas of Apron/Ramp inspection, Engineering activities, pre-flight medical, load & trim sheet, etc. The investigation team perused the reports of flight safety internal audit of last 05 years (2017-2021) submitted by the operator and following was observed: -

- There have been no findings in any of the inspections carried out during this period.
- Despite having no findings, at times it has been observed that the audit has been closed after a gap of approximately 03 months.
- In some of the cases it has been observed that the auditors (Crew) are auditing their own flights for load & trim, CVR monitoring, etc.
- The audits are being conducted without any proper system of distributing tasks to dedicated personnel who are qualified and trained in that particular area of inspection.

The above findings reflects that the safety audits are being conducted to fulfil the DGCA requirements without giving its due importance.

2.4.3.2 Safety responsibilities assigned to various post holders

The organisation in its SMS manual has formulated procedures wherein safety responsibilities has been assigned to various post holders such as safety manager, maintenance manager, etc. the safety manager is entrusted with responsibility to ensure safety promotion throughout the organization, promote effective hazard identification and reporting, etc. The maintenance manager is entrusted with responsibilities to supporting effective maintenance of the aircraft fleet, to systematically review and evaluate quality of work and inspection procedures whenever applicable technical instructions are issued to improve the standards of airworthiness and safety, to carryout spot checks to ensure that all quality standards and maintenance procedures are adhered to by all maintenance personnel, etc. In addition, all personnel in the organisation are given responsibilities to comply with the relevant safety requirements and procedures outlined in various manuals of the organisation, to advise the SMS Safety Manager of any safety occurrence or system failure and to identify and report any situation of potential risk or concern affecting system safety, etc.

Apart from above, as on date of accident the post of chief of flight safety was lying vacant since the previous post holder left the organisation in December 2021.

The observations/findings brought out during this investigation reveals that the personnel entrusted with safety responsibilities are not following these procedures. The personnel responsible for carrying out critical tasks are not following the laid down procedures. The safety procedure requires hazard identification and reporting; however, it has been observed that the mandatory reportable occurrences itself are not being reported and the facts have been concealed by responsible individuals. This implies that the personnel responsible for safe operations of flight are not adhering to the safety procedures in true letter and spirit.

2.4.3.3 Flight Data Analysis Program (FDAP)

DGCA CAR Section 5, Series F, Part II dated 25.01.2022 requires the operator to monitor and analyze one FDR for each helicopter per quarter. It also states that an operator may contract the operation of flight data analysis programme to another party while retaining overall responsibility for the maintenance of such a programme.

Accordingly, the organisation has formulated procedures in their flight safety Manual and they have outsourced the monitoring of FDR parameter exceedance to a company based in Bangalore. Certifying staff downloads the raw data and the raw data is sent to the other company for further data conversation, analysis, monitoring of FDR parameter exceedance. The company sends FDR Readout Certificate, FDR Graphical Report, FDR parameter exceedance Report to the organisation.

The investigation team perused the FDR data, analysis reports for the last few years provided by the organisation and it has been observed that there have been no exceedances found during the analysis of any of these data.

2.4.3.4 Flight Safety Awareness and Accident/Incident Prevention Programme

DGCA CAR Section 5, Series F, Part 1 requires all operators to have a Flight Safety Awareness and Accident/ Incident Prevention Programme to enhance the safety of aircraft operations. As per the CAR the requirements are applicable to all operators engaged in scheduled air transport services / Cargo Services/ non-scheduled air transport services. It is not clear whether these requirements are applicable to other operators such as State Government, Private operators, etc. However, these requirements have been made part of the flight safety manual of the organization approved by DGCA. These requirements are given in order to impart safety awareness amongst the personnel of an organization for enhancing safety. As on date of accident, no such programme has been conducted by the organization. However, safety meetings are being conducted in the organisation. As per the details of the flight safety meetings provided to the investigating team it was observed that during the meeting, DGCA CARs/ circulars/DGCA findings related to flight safety are being discussed apart from other general discussions. The details of number of personnel attended the meeting is not provided in the meeting details. The last meeting before the accident was conducted on 01 Feb 2022. Further, some safety bulletins have been issued by the organisation highlighting some accidents which occurred in India. The last safety bulletin was issued on 08.03.2021 i.e. more than 12 months prior to the accident.

Considering the fact that organisation has only 02 aircraft under its AOP out of which the helicopter met with an accident and the fixed wing aircraft is grounded since it met with the occurrence in December 2021 reflects poor accomplishment of tasks by the personnel responsible for safe aircraft operations. This also reflects that the supervision of the activities by the management is not carried out diligently.

It appears that there is lack of safety culture in the organisation. The safety culture can be built only when the Management and the personnel holding critical posts takes responsibility and ensure that each personnel in the organisation meticulously adheres to the safety guidelines and standard procedures.

2.4.4 Organisation Manuals

The organisation has formulated various manuals such as Operations Manual, Flight Safety Manual, SMS Manual, etc. as per the DGCA requirement.

During the investigation it was observed that in many places in these documents, references of previously existing Accident Investigation Rules of Aircraft Rules, 1937 and terms like inspector of accidents, etc. are mentioned which have been omitted and superseded by the Aircraft (Investigation of Accidents & Incidents) Rules, 2012 and subsequently by the Aircraft (Investigation of Accidents & Incidents) Rules, 2017. The Rules mentioned in these documents are not in line with the prevailing regulations in respect of aircraft accident investigation.

The above observations had no bearing on the accident. However, there is a need to address these issues so that the operators/organizations are aware of the current regulations in place. This will help them to act as per the regulation in place and to understand what actions are required to be carried out by them in case of accidents/serious incidents/incidents without any ambiguity.

The flight safety manual formulated by the organisation was last approved by DGCA in the year 2011. The operator re-submitted the flight safety manual to DGCA after making amendments as per the prevailing DGCA requirements. There have been number of communications made between the operator and DGCA regarding approval of the flight safety manual. However, till the date of accident, the flight safety manual was not approved by DGCA. The same is true for SMS manual also which is still under submission and not approved. Non-issuance of approved manuals containing the prevalent regulations will defeat the purpose for which these are required to be formulated. It may restrict the awareness of relevant safety procedures among the organization personnel involved in flight operations and carrying out critical tasks.

2.4.5 Unavailability of resources during the flight operations

The crew after identifying the defect during the flight returned to the Raipur airport and decided to carry out low pass over runway. The crew discussed the behavior of the helicopter and suspected that there is a possibility that the runway may be blocked after landing. Hence, they asked ATC to inform the Chief Pilot of the company to arrange for towing arm. The crew also called the Chief pilot over phone and asked to bring the towing arm to the airport. The chief pilot along with AME and towing arm reached the airport. During the final phase of first approach while carrying out low pass, the crew decided to land in this approach itself as the PIC felt that the helicopter had better controllability at that time. However, due to non-availability of towing arm the crew aborted the landing and carried out go around to allow the aircraft on ground to depart first. The unavailability of bare minimum tools required for clearing the disabled aircraft at the airport implies that there was no proper planning by the organization for conducting these flights at the airport as no tools were available in case the aircraft is met with any exigency. This was evident as the crew decided to allow the aircraft on ground to depart first before making an attempt to land. The crew probably thought that if the runway is blocked after landing it may cause unnecessary delay in the flight operations at airport.

2.4.6 DGCA surveillance and audits

DGCA carries out surveillance inspection of such operators periodically as per their annual surveillance plan. The surveillances are conducted by various Directorates of DGCA such as Air Safety, Airworthiness Directorate, etc. These surveillances are conducted by each department separately to check the compliance of regulatory requirements in the specific areas falling under their jurisdiction. Although, there have been findings specific to some areas but it does not cover the various organizational factors. Hence, the surveillance inspection of State Government Organisation as per the existing plan needs much to be desired. Further, as on date of accident no regulatory audit of the organisation has been conducted by DGCA. Since the State Government Organizations like Govt of Chhattisgarh mostly operates VIP flights, it requires comprehensive regulatory supervision in the form of Regulatory audits, etc. The organizational aspects brought out during the investigation could have been identified earlier if a comprehensive surveillance or audit of the organisation had been carried out and the accident like these could have been avoided.

2.5 Circumstances leading to the accident

The helicopter while operating the night check flight experienced tail rotor ineffectiveness which was identified by the co-pilot who was pilot flying at that time. The same was communicated to the PIC who also experienced the same.

During the examination of the tail rotor assembly after the accident, it was observed that there was loss of tail rotor pitch control in flight due to the locking nut coming off the support bearing sleeve assembly with the consequent duplex bearing disassembly, which caused furtherly the loss of connection between the slider assembly and the support bearing. The unscrewing of the locking nut was likely due to a loss of tightening torque which allowed it to move in the vibratory environment and above all favoring the progressive failure of the locking wires. This was result of poor maintenance task carried out on the helicopter during the various maintenance task requiring inspection of tail rotor assembly including disassembly/reassembly of Tail Rotor Pitch Change Mechanism. There is high probability that the tightening torque was applied low while installing the locking nut which decreased progressively in flight and came off. The maintenance tasks requiring visual inspections were also not carried out properly as per the laid down procedures otherwise the discrepancy could have been identified earlier.

After identifying that there is problem with tail rotor effectiveness, the helicopter was flown by the PIC for rest of the flight. However, no handing over/taking over controls call out were made by the crew as per the laid down procedures. The crew decided to return to Raipur and informed ATC about their intentions.

The Crew did not panic at that time and initially reacted to the emergency in accordance with the relevant RFM procedures. PIC controlled the helicopter attitude changes with Cyclic inputs and the Tail Rotor Pedal authority was checked immediately, in order to properly identify the issue.

Torque demand was managed with progressive and slow actions of the Collective, in order to both achieve a reduction in the need for anti-torque and maintain the current heading with only minimal cyclic inputs as the vertical tail fin gave the desired directional stability during that period. The crew did not carry out landing after identifying the issue and decided to carry out a low pass over runway first to ascertain the minimum speed upto which the tail rotor is effective so that they can perform landing accordingly. The ATC was also appraised about the same. There was lack of co-ordination between the crew as evident from the series of conversation between them starting from the time when the low pass over runway was performed. This lack of co-ordination resulted in two aborted landings and non-adherence to laid down procedures during critical phase of flight. Both the crew had vast flying experience and were qualified DGCA examiners on type. This probably led to a situation where they presumed that the other member will be aware of the situation and understands what actions are required to be carried out in such situation without actually sharing the task between them. Further, the co-pilot was not fully aware of the situation and not assured of the procedures to be followed in such situation. This was evident from the conversation co-pilot had with PIC throughout the flight regarding behavior of helicopter and the landing techniques in such condition. The crew suspected that there is a possibility that they may block the runway after landing, hence, asked ATC and also called the Chief pilot over phone to bring the towing arm to the airport. However, the non-availability of towing arm led to the situation where crew were indecisive in carrying out the landing and thereby allowed the aircraft on ground to depart first before making the attempt to land.

During the third approach, the helicopter successfully touched down on RWY 24 and rolled down the RWY for approximately 13s, while slowly decelerating and drifting by 8° to the RH due to tail rotor ineffectiveness resulting in slightly less antitorque control at lower speed. The PIC applied almost full AFT Longitudinal Cyclic and kept the Lateral stick neutral (except for a short LH correction approximately 8s into the landing). Collective had been moved to MPOG and consequently torque demand was minimal (18%), while both Engines were kept in FLT mode rather than executing the touchdown with selection of both Engines to IDLE or STOP which would have further reduced the resulting RH yaw.

The co-pilot did not apply brakes after touchdown and PIC was calling out repeatedly to co-pilot to apply brakes. This lack of application of brakes resulted in slow deceleration of helicopter after touch down at IAS of 52kts which reduced to only 38 kts in 12 seconds. Application of proper brakes would have resulted in a sharper deceleration and a more effective directional control on the ground.

The PIC was trying hard to bring the helicopter nose straight to align with the runway heading. However, during the landing roll after about 13s of touchdown, the co-pilot due to loss of situational awareness and probably in a state of panic applied an abrupt increase in collective (from MPOG to 66.7% in 2 seconds), which in turn caused the helicopter to lift-off again. Simultaneously to the application of Collective by co-pilot, the PIC applied parking brake as activation of the “PARK BRAKE ON” was recorded at the same time.

Immediately after the application of abrupt collective, the helicopter lifted -off again and was the trigger of the subsequent loss of control due to the lack of anti-torque control. The helicopter yawed further to the right and subsequently made at least 7-8 full 360° RH rotations with a yaw rate reaching above 360 deg/s. The helicopter climbed up to about 1680ft AMSL before descending again while spinning Clockwise up to the final impact with ground.

3. CONCLUSION

3.1 Findings

3.1.1 The Certificate of Airworthiness, Certificate of Registration and Airworthiness Review Certificate of the helicopter were valid on the day of accident.

3.1.2 The load & trim for the first flight was prepared and the C.G was within the limits.

3.1.3 There was no reported snag pending on the helicopter prior to the accident. The helicopter VT-CHG was not maintained properly as per the laid down procedures in maintenance manual.

3.1.4 Both the crew were qualified to operate the flight.

3.1.5 After identifying that there is a problem with tail rotor effectiveness, the helicopter was flown by the PIC for rest of the flight. However, no handing over/taking over controls call out were made by the crew as per the laid down procedures.

3.1.6 The crew returned to Raipur airport but did not carry out landing immediately and decided to carry out low pass over runway first to identify the minimum speed upto which the helicopter is maintaining heading.

3.1.7 There was no proper planning for any exigency being met by the aircraft at the Raipur airport as no arrangements were available for recovery in case the aircraft is met with any exigency. The non-availability of towing arm at the airport prompted the crew to discontinue landing during the first approach and carry out go around.

3.1.8 There was lack of co-ordination and application of CRM procedures between the crew which resulted in two aborted landings and non-adherence to laid down procedures during critical phases of flight.

3.1.9 The co-pilot had number of conversations with PIC throughout the flight regarding behavior of the helicopter and the landing techniques in such condition which probably implies that the co-pilot was not fully aware of the situation and not assured of handling the helicopter in such situation.

3.1.10 During the third attempt, the helicopter successfully touched down on RWY 24 and rolled down the RWY for approximately 13 seconds while slowly decelerating and drifting by 8^{o} to the RH. The crew did not follow the laid down procedures for this specific situation as both the Engines were kept in FLT mode rather than following the RFM emergency procedure which suggests crew to execute the touchdown with Engines “at the lowest possible power or even with both Engines out”.

3.1.11 The lack of application of brakes after landing resulted in slow deceleration of helicopter after touch down at IAS of 52kts which reduced to only 38 kts in 12 seconds.

3.1.12 During the landing roll after about 13s of touchdown there was an abrupt increase in collective (from MPOG to 66.7% in 2 seconds), which in turn caused the helicopter to lift-off again and lose control. Simultaneous to the application of collective, parking brake was also applied as activation of the “PARK BRAKE ON” was recorded at the same time.

3.1.13 The examination of the tail rotor assembly after the accident reveled non-adherence to the laid down procedures during the various maintenance task which led to the loss of tail rotor pitch control in flight. There were observations which also revealed that the helicopter was not maintained properly as per the laid down procedures.

3.1.14 Apart from poor maintenance practices, there is no proper updation of maintenance records.

3.1.15 The helicopter was once flown with a component which had exceeded the retirement life implies that there is no system in place to identify the components which are due for replacement/repair. This also reflects lack of safety culture within the maintenance set-up of the organisation.

3.1.16 There is no proper reporting system in the organisation. The crew along with the maintenance personnel concealed the facts regarding the occurrence involving fixed wing aircraft of the organisation which occurred in December 2021.

3.1.17 There is no proper flight safety set-up in the organisation. The safety internal audits are being conducted in the organisation without giving its due importance. There have been no findings in any of these audits during the last 05 years.

3.1.18 As per DGCA CAR Section 5, Series F, Part 1 the requirements given in the CAR are applicable to all operators engaged in scheduled air transport services / Cargo Services/ non-scheduled air transport services. It is not clear whether these requirements are applicable to other operators such as State Government, Private operators, etc.

3.1.19 The requirements given in DGCA CAR Section 5, Series F, Part 1 have been made part of the flight safety manual of the organization approved by DGCA. As on date of accident, no safety programme has been conducted by the organization.

3.1.20 Safety meetings are being conducted in the organisation, however, the details of number of personnel attended the meeting is not provided in the meeting details. Safety bulletins have been issued by the organisation highlighting some accidents which occurred in India. The last safety bulletin was issued on 08.03.2021 i.e. more than 12 months before the accident.

3.1.21 The investigation team observed lack of safety culture in the organisation and the required safety standards are not being met. The personnel entrusted with safety responsibilities and carrying out critical tasks are not following the laid down procedures diligently.

3.1.22 The investigation team perused the FDR data analysis reports carried out under FDAP which was provided by the operator. It has been observed that there have been no exceedances found during the analysis of any of these data during the last few years.

3.1.23 The organisation has only 02 aircraft under its AOP out of which the helicopter met with an accident and the fixed wing B200 aircraft was grounded for long since it met with the occurrence in December 2021 reflects poor accomplishment of tasks by the personnel responsible for safe aircraft operations. This also reflects that the supervision of the activities by the management is not carried out diligently.

3.1.24 DGCA carries out surveillance inspection of operator periodically as per their annual surveillance plan. However, as on date of accident no regulatory audit of the organisation has been conducted by DGCA. Since the State Government Organizations like Govt of Chhattisgarh mostly operates VIP flights, it requires comprehensive regulatory supervision.

3.2 Probable cause of the accident

The accident occurred as the helicopter with lack of tail rotor effectiveness, lost control due to application of abrupt collective pull during landing roll causing the helicopter to lift-off again and enter into uncontrolled spin before descending and impacting the ground. The abrupt application of collective pull during the landing roll can be attributed to loss of situational awareness and state of panic as the crew were unable to bring the helicopter nose to the runway heading even after 13 seconds of touchdown.

The following factors contributed to the accident: -

- Lack of co-ordination between the crew and non-adherence to CRM procedures.
- Non-adherence to laid down RFM emergency procedures.
- Poor maintenance practices which resulted in tail rotor ineffectiveness during flight.
- Lack of safety culture in the organisation.
- Lack of supervision of aircraft operations and maintenance.

4. SAFETY RECOMMENDATIONS

4.1 The helicopter was not maintained properly as per the laid down procedures and the practice of poor maintenance existed in the organisation. It is recommended that the operator may re-look into their maintenance setup and formulate specific procedures to ensure that

a) The maintenance personnel follow the best practices and strictly adheres to the laid down procedures.

b) All maintenance activities (including upkeep of maintenance records) are supervised at appropriate level and any discrepancy found are corrected without any delay.

4.2 It is recommended that, DGCA during their surveillance/inspection of the organisation may give more emphasis on the maintenance practices being followed by the organisation.

4.3 There was no proper planning for conducting these flights at the airport as no tools/arrangements were available at the airport for recovery in case the aircraft is met with any exigency. Non-availability of towing arm at airport led to a situation where crew were indecisive in carrying out landing immediately. It is recommended that DGCA may issue directions to all NSOP/State Govt/Pvt. operators (having base in city and operates regularly from the main airport) to make sure that minimum tools/arrangements required for recovery of the aircraft is available at the main airport to ensure timely removal of the aircraft in case of any exigency.

4.4 Lack of co-ordination and non-adherence of SOP during critical phases of the flight contributed to the accident. It is recommended that DGCA may issue directions (as deemed fit) to all operators to strictly adhere to SOPs while undertaking re-current training flights with TRE/TRI so as to avoid scenarios (as in the present case) leading to poor co-ordination and confusion in handling of aircraft during critical phases of flight.

4.5 It is recommended that DGCA may issue directions to all helicopter operators to give more emphasis on critical emergencies (including tail rotor ineffectiveness) during re-current training on simulators and also during the ground classes.

4.6 There is no proper flight safety set-up in the organisation. The safety procedures were not followed meticulously. It is recommended that DGCA during their surveillance/audit may give more emphasis on functioning of flight safety set-up of such organisations (specially the State Government Operators/small Operators with 01 or 2 aircraft under their AOP) so that the safety procedures such as internal audits, Flight Data Analysis under FDAP, etc. are followed meticulously.

4.7 The requirements given in DGCA CAR Section 5, Series F, Part 1 are applicable to all operators engaged in scheduled air transport services / Cargo Services/ non-scheduled air transport services, however, it is not clear whether these requirements are applicable to other operators such as State Government, Private operators, etc. It is recommended that DGCA may consider amending the CAR Section 5, Series F, Part 1 to include other operators such as State Government, Private operators, etc. The regulatory requirements for such operators under this section may be framed accordingly.

4.8 DGCA carried out periodic surveillance of the organisation as per annual surveillance plan, however, no regulatory audit of the organisation was carried out till the day of accident. It is recommended that, DGCA may re-look into the existing surveillance plan for the State Government organisations and consider conducting comprehensive periodic supervision in the form of Regulatory Audit, etc. to give emphasis on the organisational factors which may lead to non-compliance of laid down regulatory requirements.

4.9 There was lack of safety culture in the organisation. The observations/findings brought out during this investigation revealed that the personnel entrusted with safety responsibilities were not following these procedures diligently. It is recommended that, DGCA may issue instructions/directions as deemed fit to all operators like State Government/ Small Operators, etc. to develop means to enhance safety culture in their organization. This may be achieved by periodically conducting safety related programs/activities wherein it is ensured that every individual responsible for safe conduct of flight participate in these programs so that they are encouraged to follow the laid down procedures/guidelines in true letter and spirit. The compliance of the same may be checked and verified during audits/surveillance of these organizations.

4.10 The flight safety manual and SMS manual of the organisation was not approved by DGCA as on date of accident. The flight safety manual was last approved in the year 2011. It is recommended that, DGCA may consider developing methodologies to ensure that the manuals such as flight safety manual, SMS manual, etc. are submitted by the operator in time for approval. Further, it may be ensured that these manuals contain the existing regulations/procedures at the time of their submission.

Date: 21 January 2025

Place: New Delhi

APPENDIX ‘A’

ROTORS FLIGHT CONTROL SYSTEM

The rotors flight controls system permits to control the helicopter throughout its flight envelope. This controls system provide to control vertical flight, level flight and direction of the helicopter, and all possible combinations. The rotors flight control system comprises the main rotor control system, the tail rotor control system and the servo control system.

The main rotor control system in turn comprises the collective pitch control systems, the cyclic pitch control system and the mixing control system. The collective, cyclic and tail rotor pitch controls are rigid, servo-assisted type, and are respectively connected to the collective levers, to the cyclic stick and anti-torque control pedals.

The flight controls consist of levers, bellcranks, supports, fixed and adjustable control tubes. The adjustable control tubes permit the rigging of the flight controls. The helicopter incorporates two actuators in the cyclic control system and a single actuator in the tail rotor pitch control system as provision for the helipilot system to increase helicopter stability.

Two toe pedals are installed on the pilot’s anti-torque pedals and are used to control the brakes of the main landing gear. The collective, cyclic, and anti-torque control systems incorporate friction controls to vary the effort necessary to move the controls.

The movements of the collective lever (6,7) and the cyclic stick (1,3) are transmitted through separate linkages to the mixing group (9) installed on the upper deck of the fuselage.

The mixing group consists of a support connected to a carriage assembly on which the mixing lever pivots (14).

The movements of the collective lever cause longitudinal movement of the carriage assembly, and of the connected mixing lever assembly. The longitudinal movement of the carriage assembly actuates the servo actuator valves causing a corresponding and equal retraction or extension of the servo actuator rods. The extension or retraction of the servo actuator rods connected to the swashplate pitch horn causes the upward or downward movement of the swashplate changing the pitch angle of the main rotor blades.

The movements of the cyclic stick cause pivoting of the mixing lever assembly (14) which, through a linkage, actuates the servo actuator valves causing a corresponding extension and retraction of the servo actuator rods.

The combination of extension and retraction of the servo actuators rods tilts the swashplate with a consequent change of the plane of rotation of the main rotor blades.

The movements of the tail rotor anti-torque pedals are transmitted through a linkage, causing the extension or retraction of the servo actuator and the consequent change in pitch of the tail rotor blades.

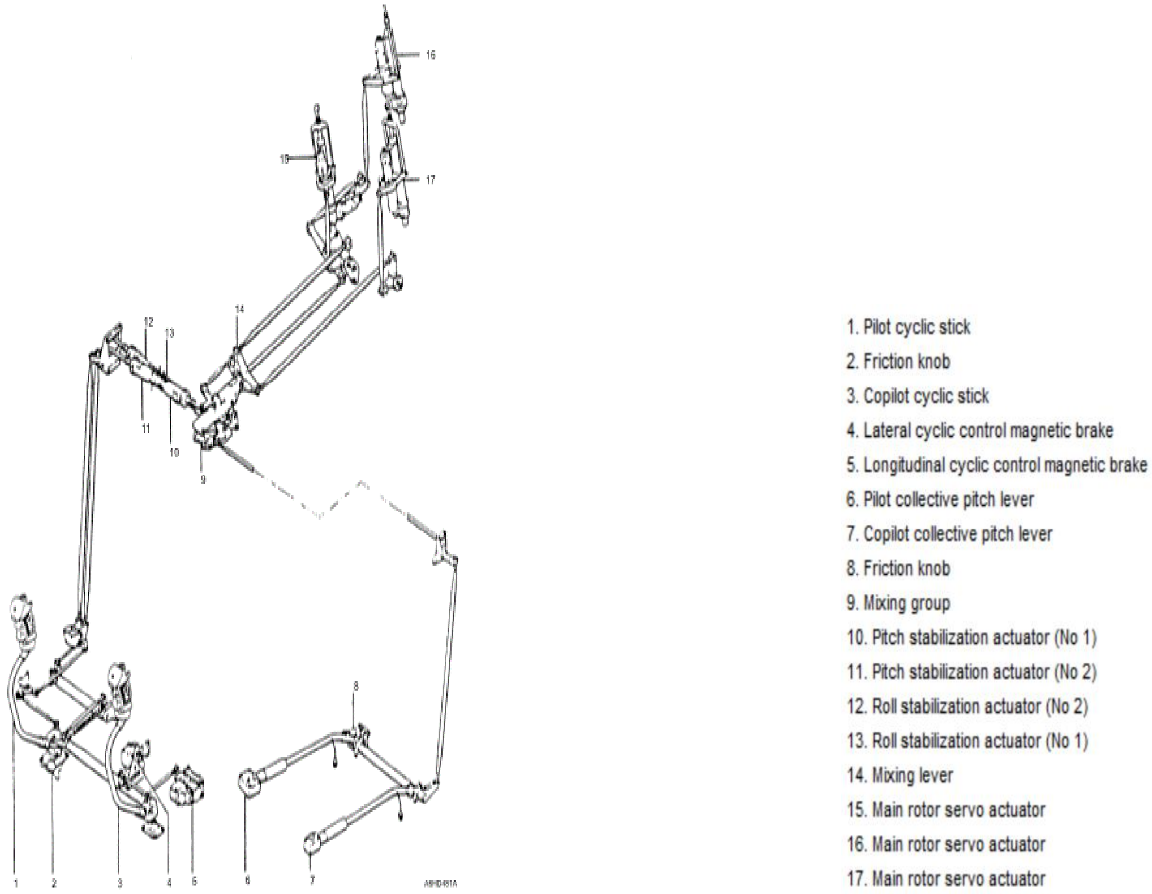


Fig 1. Rotors Flight Control System

<u>Rotors Flight Control System Controls and Indicators (Figure 2)</u>

The rotors flight control system controls and indicators comprise:

- Cyclic Stick (1). The cyclic stick operated by means of tubes and bellcranks, the mixing lever which in turn actuates the servo actuators valves, causing a corresponding extension or retraction of the servo actuator rods; combined extension and retraction of the servo actuator rod tilts the swashplate with a consequent change of the plane of rotation of the main rotor blades.
- FTR Push-Button Switch (2): When pushed, causes release of the cyclic and tail rotor pitch magnetic brakes. When the push-button is released the magnetic brakes re-engage.
- F-TRIM Switch (3): When set in ON position it causes engagement of the cyclic and tail rotor pitch magnetic brakes. When set in off position the magnetic brakes are released.
- Tail Rotor Pedal Sets (5): Operates, by means of tubes and bellcranks, the pitch change mechanism mounted on the 90-degree gearbox output shaft. Pitch change commands are transmitted to the blades by two links. The servo actuator is connected to the linkage in offset position.
- Pedal Set Adjustment Knobs (6): Permits adjustment of the distance between the pedal sets and the pilot seats.
- Collective Levers: Operate, by means of tubes and bellcranks, the mixing group and the mixing lever. The longitudinal movement of the mixing group carriage actuates the servo actuator valves causing a corresponding retraction or extension of the servo actuator rods; extension or retraction of the servo actuator rods, connected to the swashplate pitch horns, causes the

upward or downward movement of the swashplate with consequent changing of the main rotor blade pitch angle.

- Friction Control Knob: Permits adjustment of the force required to move the collective lever.

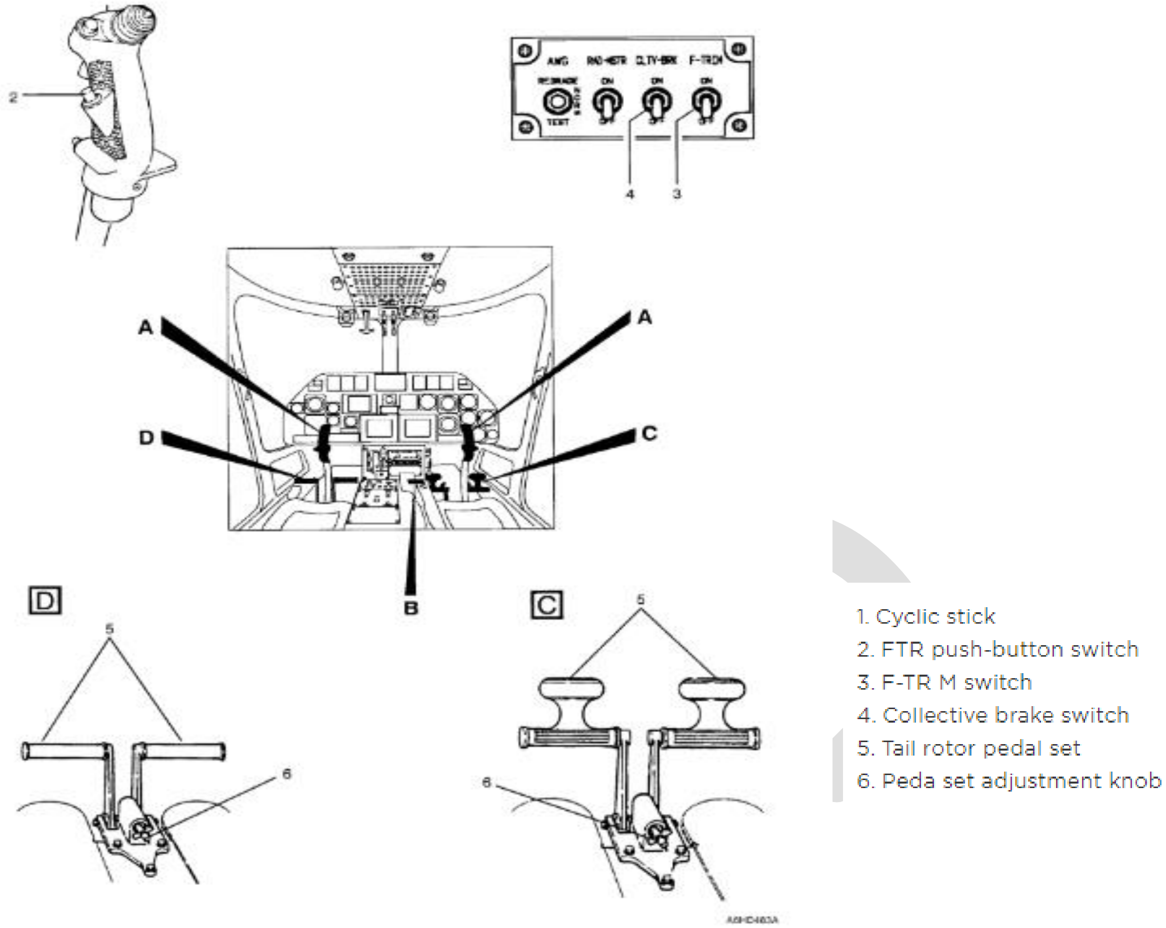


Fig 2. Rotors Flight Control System (Cyclic Stick & TR Pedals)

Collective Pitch Control System (Figure 3)

The system is a conventional rigid control tube type and is controlled by the collective lever located on the left side of the pilot seats. Movements of the collective lever are transmitted by the control system to the mixing group. The force required to the collective control can be adjusted by operating the adjustable friction knob (13). The control can be locked in any position by tightening the friction knob completely. The copilot controls are identical to the pilot controls with the exception of the collective lever switch box. The system incorporates a collective pitch magnetic brake.

Collective Pitch Control Lever (Figure 4)

The collective pitch control lever is located on the left side of the pilot’s seat and is fixed to the torque tube (9). The lever consists of a shaped light-alloy tube incorporating a cork-encased grip and a switch box at the upper end.

Switch Box (Figure 4)

The switch box is installed on the upper end of the collective lever and is held in position by a pin. A typical switch box incorporates the following controls:

- ENG 2 AUTO/MANUAL control switch (1)
- Landing light control switch (2)

- ENG 2 Trim switch (3)
- ENG 1, trim switch (4)
- Go around switch (5)
- Master caution/warning light reset switch (6)
- Limit override push-button (7)
- RPM selector switch (8)
- ENG 1 AUTO/MANUAL control switch (9).

<u>Torque Tube (Figure 3)</u>

A torque tube (9), located beneath the left seat, interconnects the collective lever (16, 19) and control tube (4). It is supported at its inboard end by the adjustable friction unit (13), and at its outboard end by a sealed bearing in support (7).

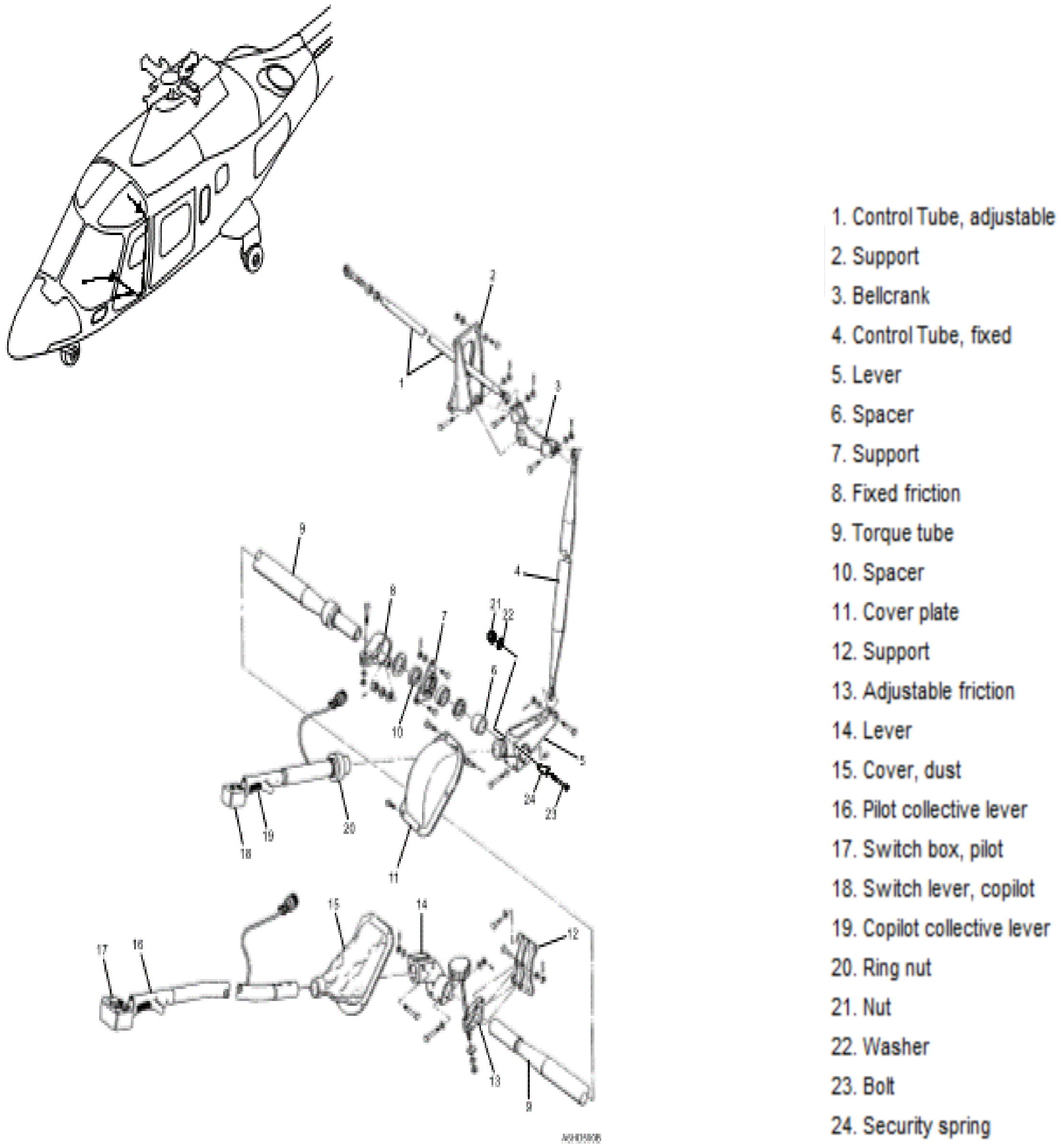


Fig 3. Collective Pitch Control System

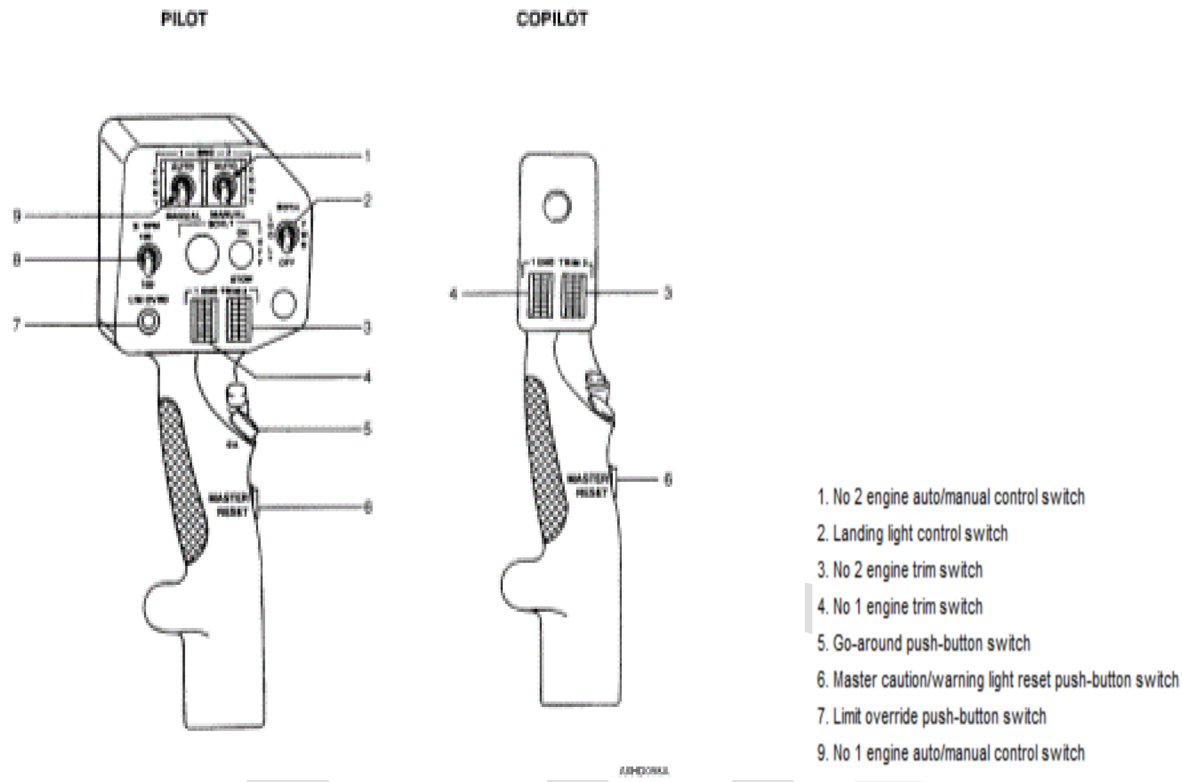


Fig 4. Collective Pitch Control Lever & Switch box

<u>Cyclic Pitch Control System (Figure 5 & 6)</u>

The system is a conventional rigid control tube type and is controlled by the pilot and co-pilot operating the cyclic sticks (1, 24). Control movements are transmitted by the system to the mixing group and will cause tilting of the mixing lever pivoted on the group. The force necessary to operate the control may be adjusted by the friction control (14). The control can be locked in any position by tightening the knob completely. The system incorporates two magnetic brakes trim and feel units (18, 19) and two control tubes with stabilization actuators.

<u>Cyclic Pitch Control Sticks (Figure 5 & 6)</u>

Each cyclic pitch control stick, located in front of the pilot and copilot's seat, consists of an h-shaped tube, in light alloy. The lower end of the stick, protected by a boot, is fixed to the self aligning bearing of support (15) to enable control movements in all direction. At the upper end of the stick is fitted the handgrip.

<u>Cyclic Pitch Control Stick Handgrips (Figure 7)</u>

Each cyclic pitch control stick is equipped with an anatomical handgrip, made of synthetic material and secured to the stick with a screw. The handgrip incorporates the controls listed in Figure 16.

<u>Control Stick Support Group (Figure 5 & 6)</u>

The cyclic control stick is supported by a group which consists of a lever (16) and a support (15). The lever houses the bottom end of the control stick and is connected to the support by means of a ball bearing which allows the lever to tilt in all directions. The support is slotted in order to function as a friction device in which adjustable pressure is applied by the support on the bearing outer race. The bearing pivot free end is provided with a seat for the insertion of a pin to position the stick during system rigging. The left lever and support (22, 21) are similar to right lever and support described above except for the friction. The two groups are interconnected by a torque tube (12) and are secured with bolts to the fuselage lower structure.

Torque Tubes (Figure 5 & 6)

The cyclic pitch control system incorporates two light alloy torque tubes (6, 12) located in the compartment below the cockpit seats.

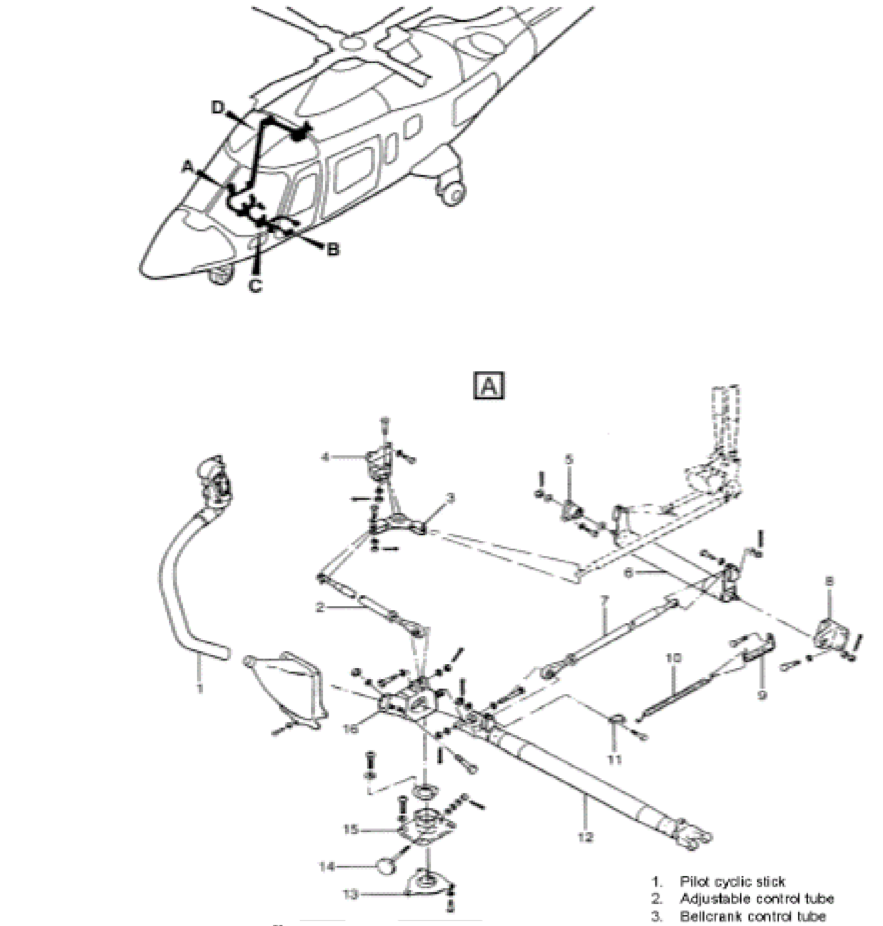
The forward torque tube is mounted on and interconnects the control stick support groups. The aft torque tube is mounted on supports (5, 8) on the helicopter structure. Both torque tubes incorporate end levers for control tube connection.

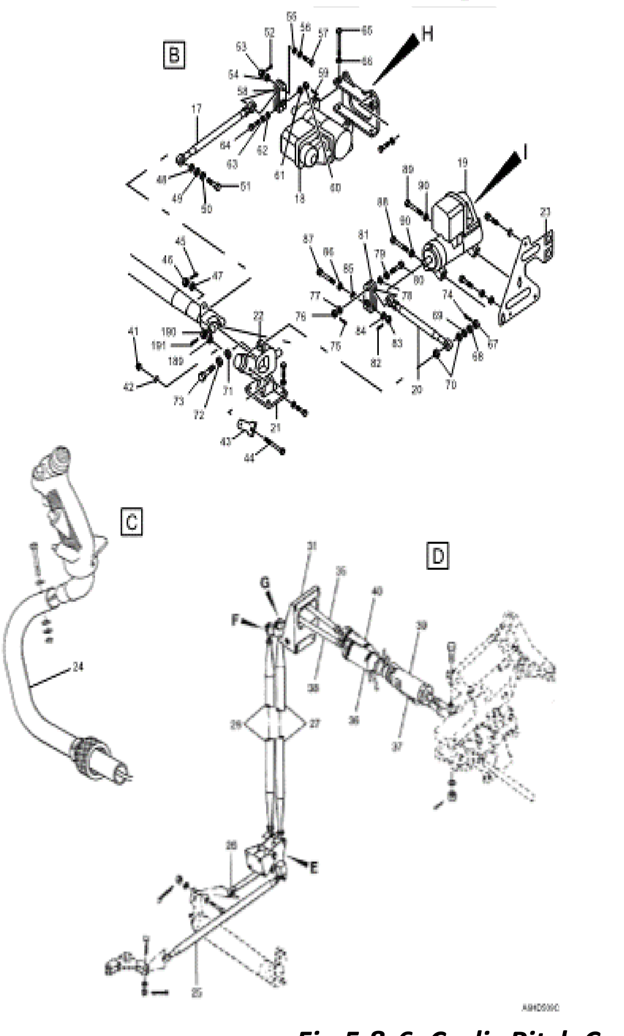
Magnetic Brake Artificial Feel and Trim Units (Figure 5 & 6)

The cyclic pitch control system is equipped with two magnetic brake artificial feel and trim units (18, 19). When the Autotrim system is not installed or is inoperative, the artificial feel and trim units function as two magnetic brakes to permit variation of cyclic stick reference point and also to create artificial feel to counter stick movement from the reference point. When the Autotrim system is installed the artificial feel and trim units perform the functions of the magnetic brakes and also incorporate an electric motor which permits automatic variation of cyclic control stick reference center (Autotrim). When the helipilot actuators incorporated in the cyclic pitch control linkage have for a predetermined period at over 30% of their range of travel, the artificial feel and trim units automatically intervene to alter the cyclic stick reference center. The attitude of the helicopter is maintained unchanged while the helipilot actuators are returned mid-travel position. The artificial section of units are powered by 28, DC from bus-bar N. 1 through the FORCE TRIM circuit breakers located on overhead panel. The actuator electric motors are powered by 28V DC from bus-bar No 1 through the AUTO TRIM circuit breaker located on overhead panel.

Stabilization Actuators (Figure 5 & 6)

The cyclic pitch control system incorporates two control tubes with stabilization actuators (37, 39) which function to stabilize the helicopter in response to electrical control signals supplied by the stabilization system. Each control tube is composed of two actuators independently connected each to one stabilization system thus assuring adequate helicopter stability in the event of failure of one stabilization system.





1. Pilot cyclic stick
2. Adjustable control tube
3. Bellcrank control tube
4. Support
5. Support
6. Torque tube
7. Adjustable control tube
8. Support
9. Bracket
10. Spring
11. Bracket
12. Torque tube
13. Centering plate, cover
14. Friction control
15. Support
16. Lever
17. Adjustable control tube
18. Longitudinal magnetic brake
19. Lateral magnetic brake
20. Adjustable control tube
21. Support
22. Lever
23. Plate
24. Copilot cyclic stick
25. Fixed control tube
26. Fixed control tube
27. Adjustable control tube
28. Adjustable control tube
29. Bellcrank
30. Bellcrank
31. Support
32. Bellcrank
33. Support
34. Bellcrank
35. Control tube with stabilization actuators
36. Cyclic stabilization actuator (No 2 lateral)
37. Cyclic stabilization actuator (No 1 lateral)
38. Control tube with stabilization actuators
39. Cyclic stabilization actuator (No 1 longitudinal)
40. Cyclic stabilization actuator (No 2 longitudinal)
41. Nut
42. Washer
43. Security bolt
44. Bolt
45. Cotter pin
46. Nut
47. Washer
48. Washer
49. Washer
50. Washer
51. Bolt
52. Cotter pin
53. Nut
54. Washer
55. Washer
56. Washer
57. Bolt
58. Lever
59. Cotter pin
60. Nut
61. Washer
62. Washer
63. Washer
64. Bolt
65. Bolt
66. Washer
67. Nut
68. Washer
69. Washer
70. Sleeve
71. Washer
72. Washer
73. Bolt
74. Cotter pin
75. Cotter pin
76. Nut
77. Washer
78. Washer
79. Washer
80. Bolt
81. Lever
82. Cotter pin
83. Nut
84. Washer
85. Washer
86. Washer
87. Bolt
88. Bolt
89. Bolt
90. Washer
91. Bolt
92. Washer
93. Washer
94. Nut
95. Cotter pin
96. Bolt
97. Washer
98. Washer
99. Washer
100. Nut
101. Cotter pin
102. Bolt
103. Washer
104. Washer
105. Washer
106. Nut
107. Cotter pin
108. Bolt
109. Washer
110. Washer
111. Nut
112. Cotter pin
113. Bolt
114. Washer
115. Nut

Fig 5 & 6. Cyclic Pitch Control System

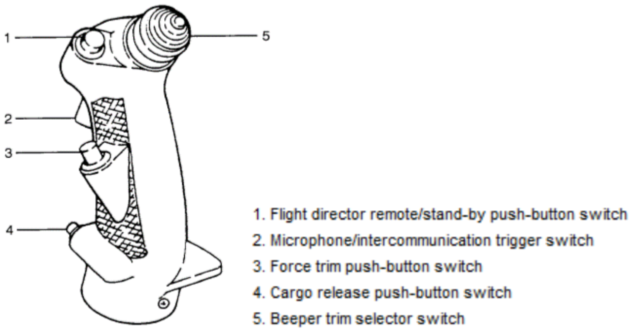
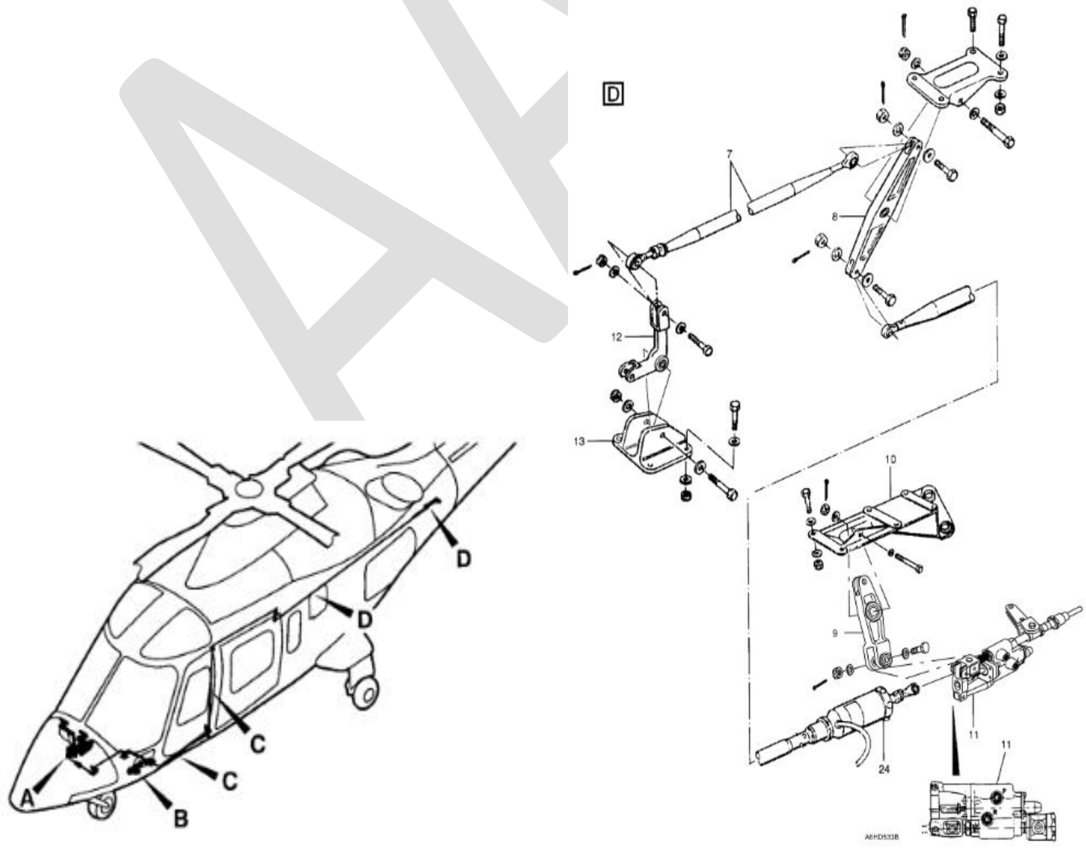


Fig 7. Cyclic Pitch Control Stick Handgrips

<u>Tail Rotor Control System (Figure 8)</u>

The tail rotor control system is controlled thru the use of two adjustable-reach, tail rotor pedals which are connected by a series of levers, push-pull tubes, and bellcranks, to the tail rotor hydraulic servo actuator (11). An output lever (9) connected to control tube (25) transmits movements of the actuator to the tail rotor pitch change mechanism, causing variation in the pitch of tail rotor blades. The system incorporates a control tube provided with stabilization actuator (24), and a magnetic brake (17). A friction adjustment (19) located on at bellcrank (18) is preset, during rigging, to establish a minimum friction in the system. A spring (26) is installed between the lever (9) and a support in the tail boom. In case of slow speed flight and of a No 1 hydraulic system leakage, the spring reduces the yaw.



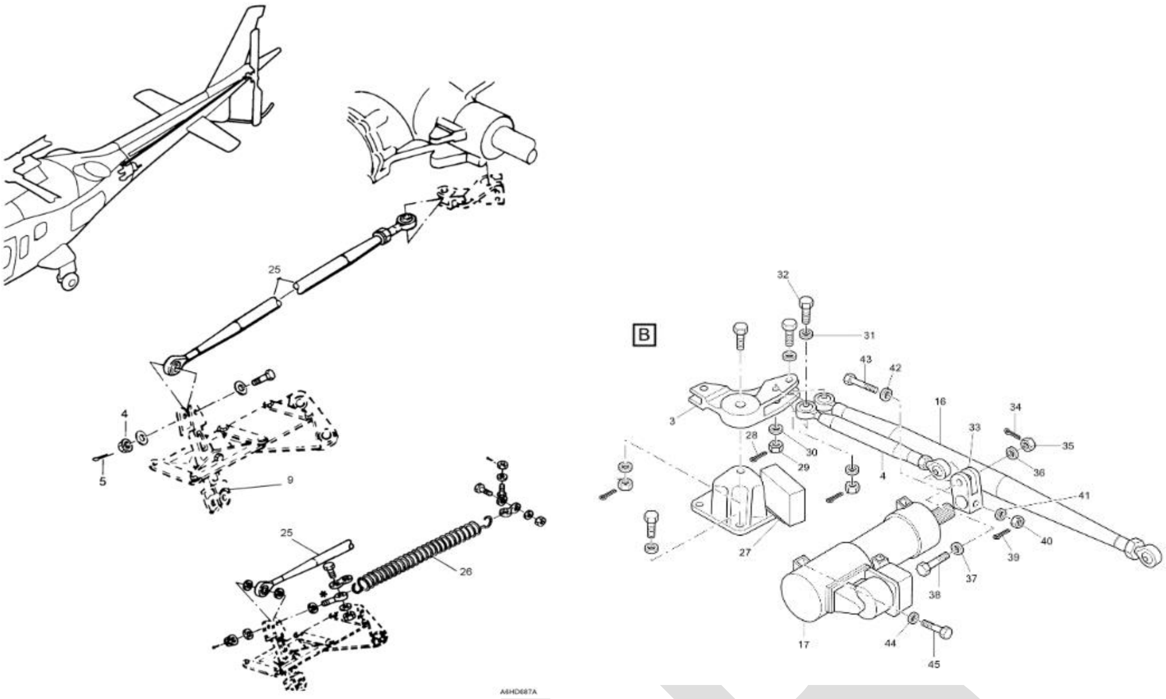


Fig 8. Tail Rotor Control System

Anti-Torque Pedals (Figure 9)

The anti-torque pedals are secured to the cabin floor facing the pilot’s seat. The pedals are attached to a support (7) on which the pedals are hinged and connected to the link-rods (10 and 12) which actuate the lever (11). The pedals are fitted with a device for adjusting the distance between the pedals and the pilot’s seat. The pilot’s pedals are fitted with toe brakes (1) for braking the main landing gear wheels.

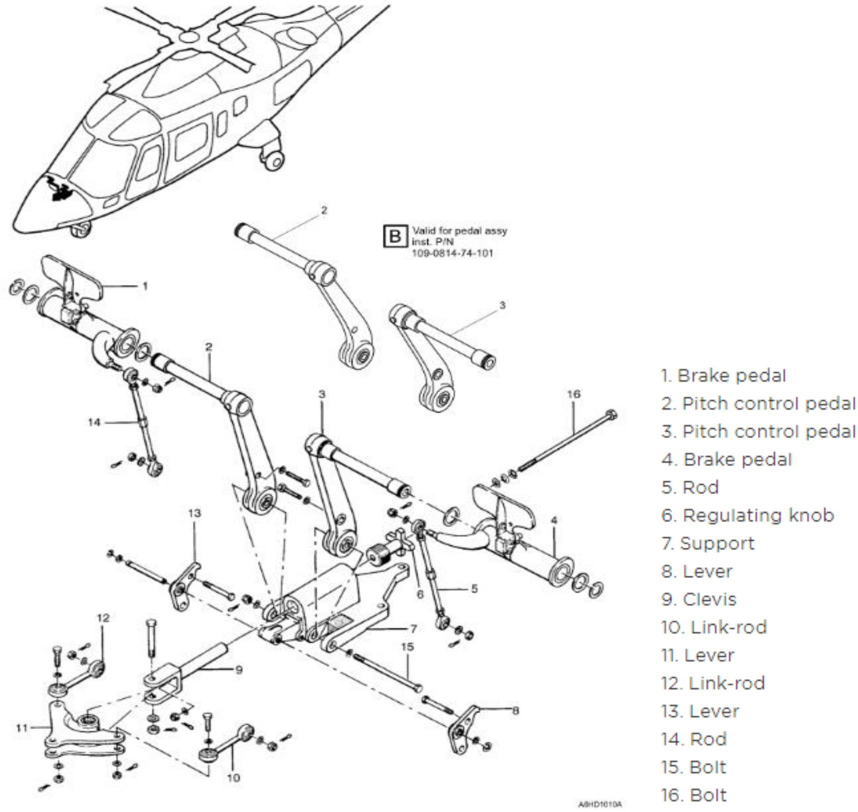


Fig 9. Anti – Torque Pedals

Torque Tube (Figure 10)

The torque tube (15) is a light alloy tube installed beneath the left door post of the crew cabin. The torque tube is mounted on supports (5, 14) secured to the helicopter structure, and incorporates two end levers for control tube connection.

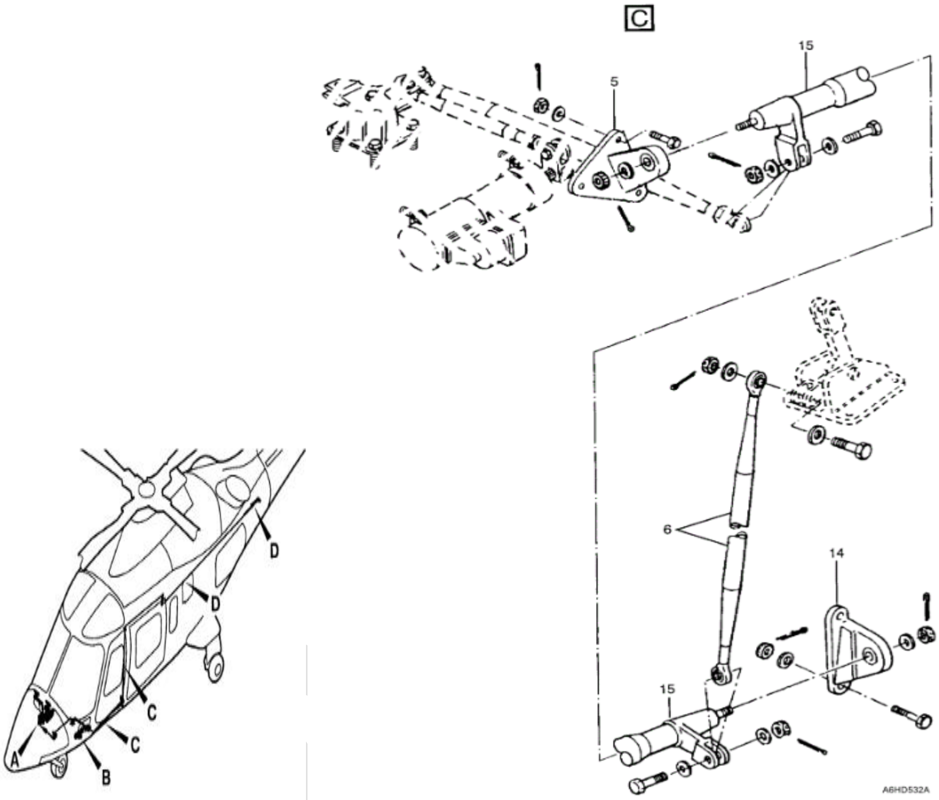


Fig 10. Torque Tube

Magnetic Brake Artificial Feel Units

The magnetic brake artificial feel units (17) installed in the tail rotor pitch control system is almost identical to the cyclic magnetic brake. Magnetic brake is controlled by F-TRIM switch located on the pedestal; FTR switch on the cyclic control handgrip permits a temporary release of magnetic brake. Magnetic brake is powered by 28 V dc from bus bar no 1 through AUTO TRIM circuit breaker.

Stabilization Actuator

The tail rotor pitch control system incorporates a control tube with stabilization actuator (24) which function to stabilize the helicopter in response to electrical control signals supplied by stabilization system.

WHEEL BRAKE SYSTEM

Wheel brake system hydraulic circuit

The main landing gear wheels are provided with disc-type brakes, hydraulically operated by the control valve mechanically connected to the brake pedals fitted on the pilot tail rotor pedal set. The hydraulic power to operate the control valve is supplied by the normal circuit of utility hydraulic system. If no pressure is available in the normal circuit, the brakes can be operated using the pressure of the emergency circuit; in the case, however, the brakes are not applied by means of the pedals but by operation of the PARK AND EMERG BRAKE handle, through the nose gear centering lock and brake selector valve. The schematic of the wheel brake system hydraulic circuit is illustrated in figure.

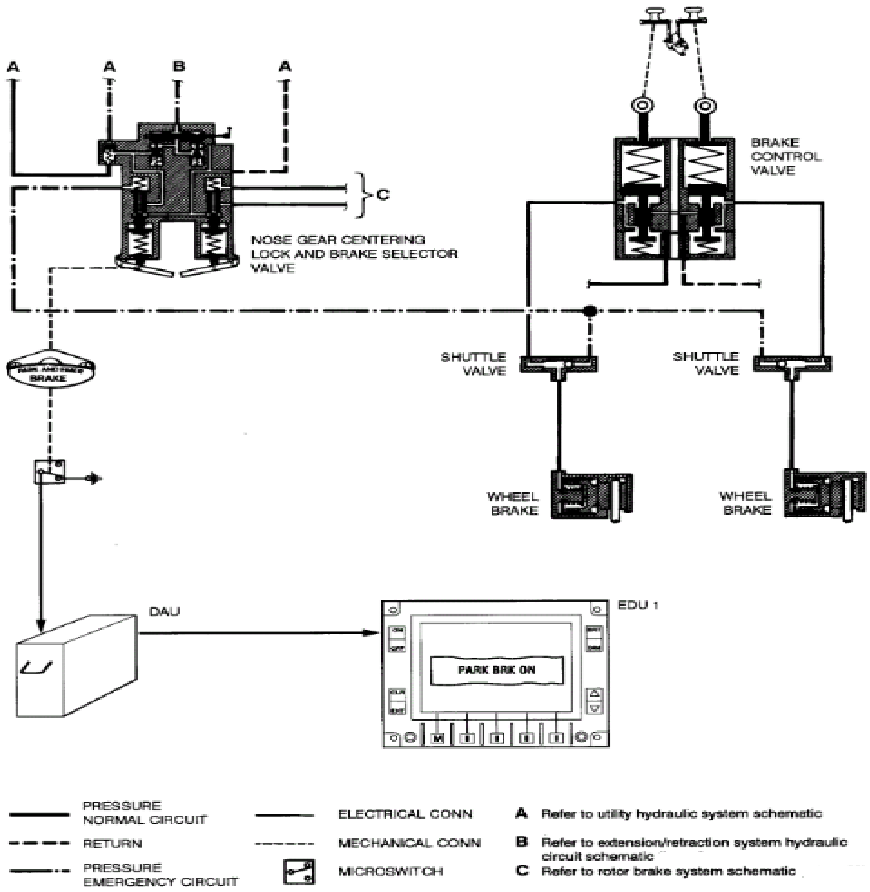


Fig 11. Wheel Brake System

Nose Gear Centering Lock and Brake Selector Valve

The nose gear centering lock and brake valve is installed in the right side of the nose compartment. The selector valve is a multi-purpose hydraulic unit designed to operate the main rotor brake circuit, wheel brake emergency (and parking) circuit and nose gear centering lock circuit. The main rotor brake and wheel brake emergency control section consist of two identical cylinders, each actuated by a lever.

The nose gear centering lock section consists of a three-way, two-position selector valve, controlled by a shaft. All components are enclosed in a body provided with six ports. The wheel brake emergency and parking cylinder is controlled by the PARK AND EMER BRAKE handle, on the front console. The nose gear centering lock selector valve is controlled by the NOSE WHEEL LOCK lever on the front console. The main rotor brake cylinder is controlled by the ROTOR BRAKE lever on overhead console.

Brake control valve

The brake control valve is installed on a support located below the pilot seat and is controlled by a system of rods and levers connected to the brake pedals installed on the pilot tail rotor pedal set. The control valve has the function to pressurize the wheel brake circuit. The control valve consists of two identical master cylinders enclosed in a body provided with four ports. Each master cylinder is provided with a rod end, with integral bearing, for connection of control linkage.

Shuttle valves

Two shuttle valves are incorporated in the wheel brake hydraulic circuit. The shuttle valve is designed to connect the wheel brake to either the normal or emergency circuit. It also acts a check valve by preventing fluid from flowing from the pressurized side to the non-pressurized side. The unit consists mainly of body with internally threaded ports and outlet fitting, two inlet unions and a ball valve.

Wheel brake

The wheel brakes are installed on the axles of the main landing gear wheels. The brake consists of a stationary and rotating section. The stationary section, which is secured to the gear axle, comprises a housing assembly and a back plate. The housing assembly contains two piston assemblies, a fitting for connection of the hydraulic line and a bleeder valve. Each piston assembly consists mainly of a liner, a return spring, a compensating friction device and a lining. The compensating friction device, which consists of two cones and a drag ring is provided to compensate piston stroke due to wear of linings, to assure, in absence of hydraulic pressure, a gap between disc and linings. The back plate contains two linings. The rotating section consists of a disc keyed to the wheel by six teeth secured to the wheel half.

E. FRONT CONSOLE

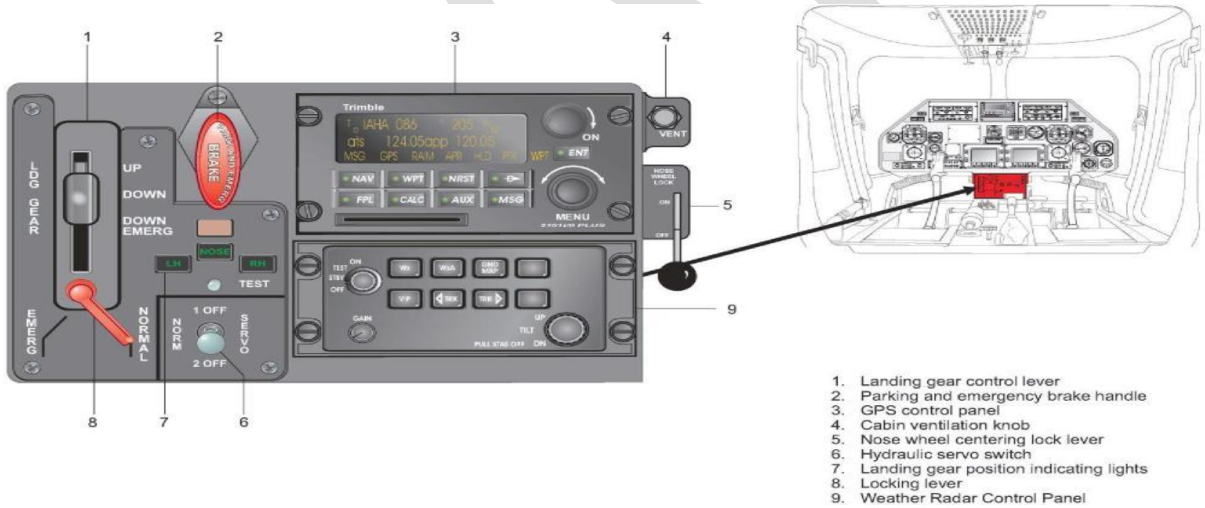


Fig.12: Overview of the A109E Front Console with the LG control & indicating system

Parking brake advisory circuit

The parking brake is provided with an advisory circuit consisting of the PARK BRK ON caution legend which comes in view on the EDU 1 when the parking brake is applied. A switch (S7606) actuated by the parking brake handle feeds the signal to DAU which controls the EDUs. The switch circuit is directly powered by the DAU and is an integral part of the warning, caution and advisory system of the IDS.

APPENDIX 'B'

PHOTOGRAPHS OF TAIL ROTOR COMPONENTS WITH OBSERVATIONS MADE DURING ITS EXAMINATION

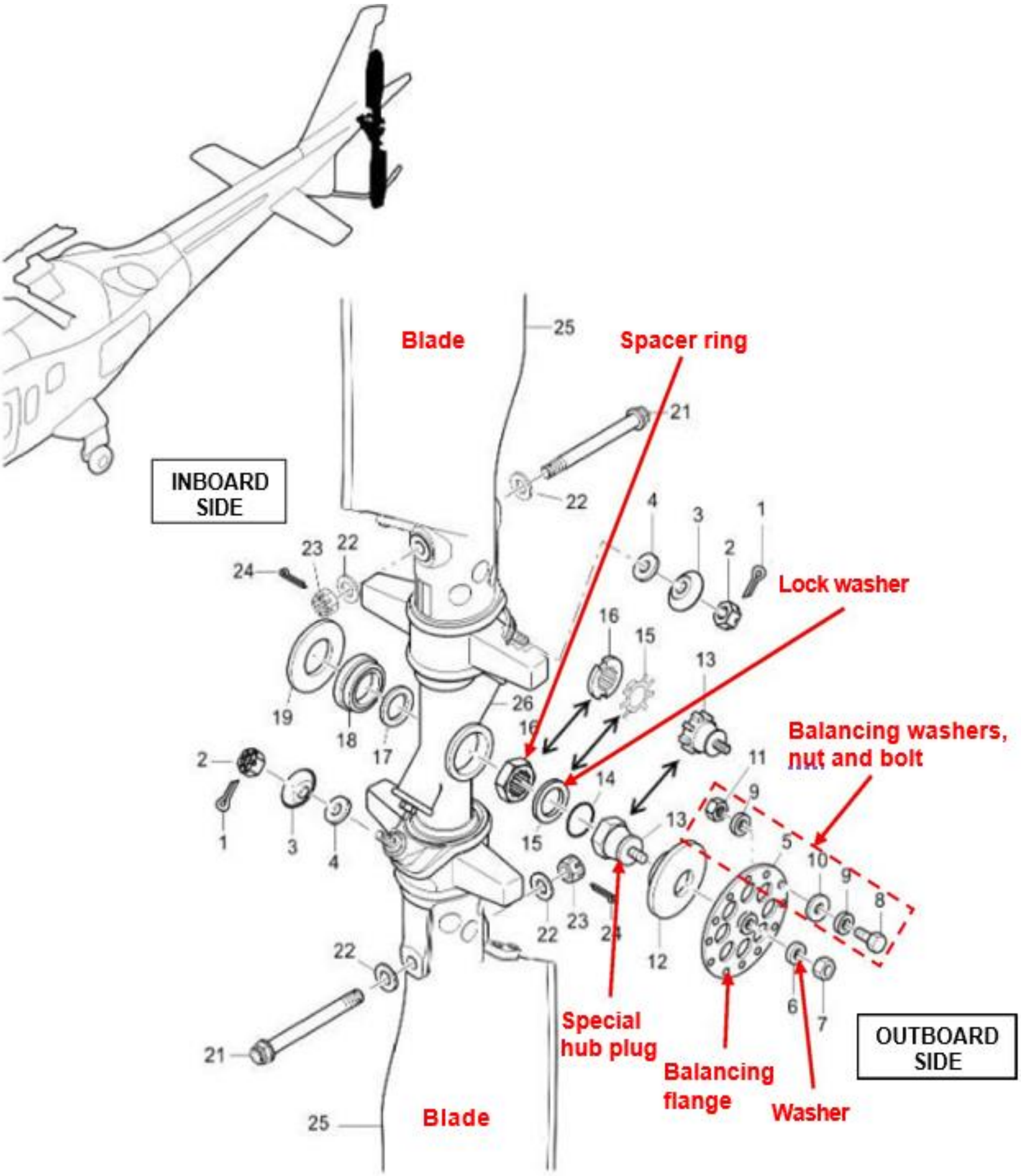
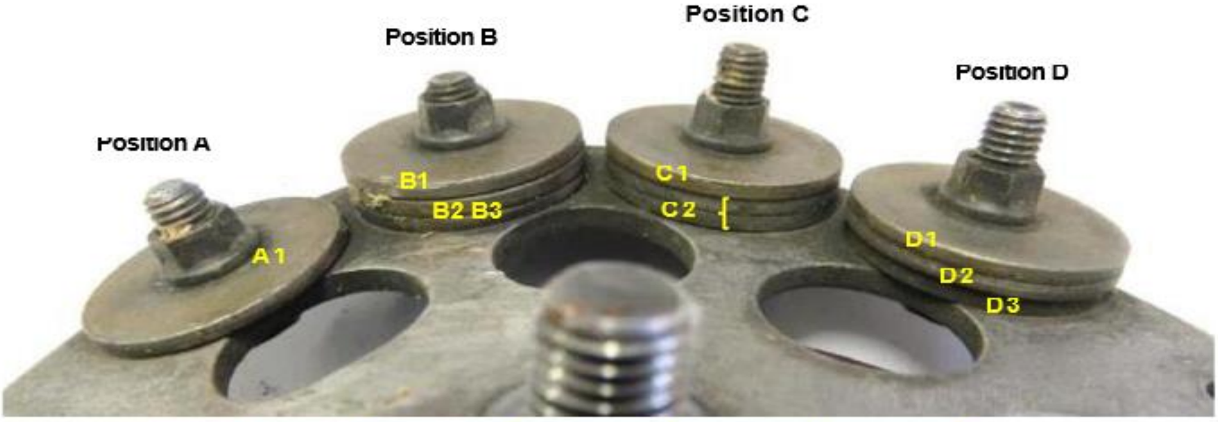


Figure 1 – Exploded view drawing of the tail rotor installation, with indication of the relevant parts for the investigation.

Figure 2 – Details of the deformed balancing flange and the absence of the washer to be installed mating to it (Fig. 1).



	Position A - Weight	Position B - Weight	Position C - Weight	Position D - Weight
Bolt	3,188	3,387	3,865	3,702
Nut	0,827	0,806	0,829	0,83
Washer 1	4,724	4,722	4,707	4,704
Washer 2		4,722	8,94	4,632
Washer 3		4,713		4,132
TOT	**8,739**	**18,35**	**18,341**	**18**

Figure 3 – Details of the washers applied on the balancing flange and the measured weight of the masses (washers, nut and bolt) for each position, which proved to be compliant with the maintenance manual. The C2 weighing includes two washers that could not be easily separated.

Figure 4 – Details of the test performed on the blades to verify the freedom of rotation around their longitudinal axis (red arrows). The hub was engaged on a test TR gear box output shaft.

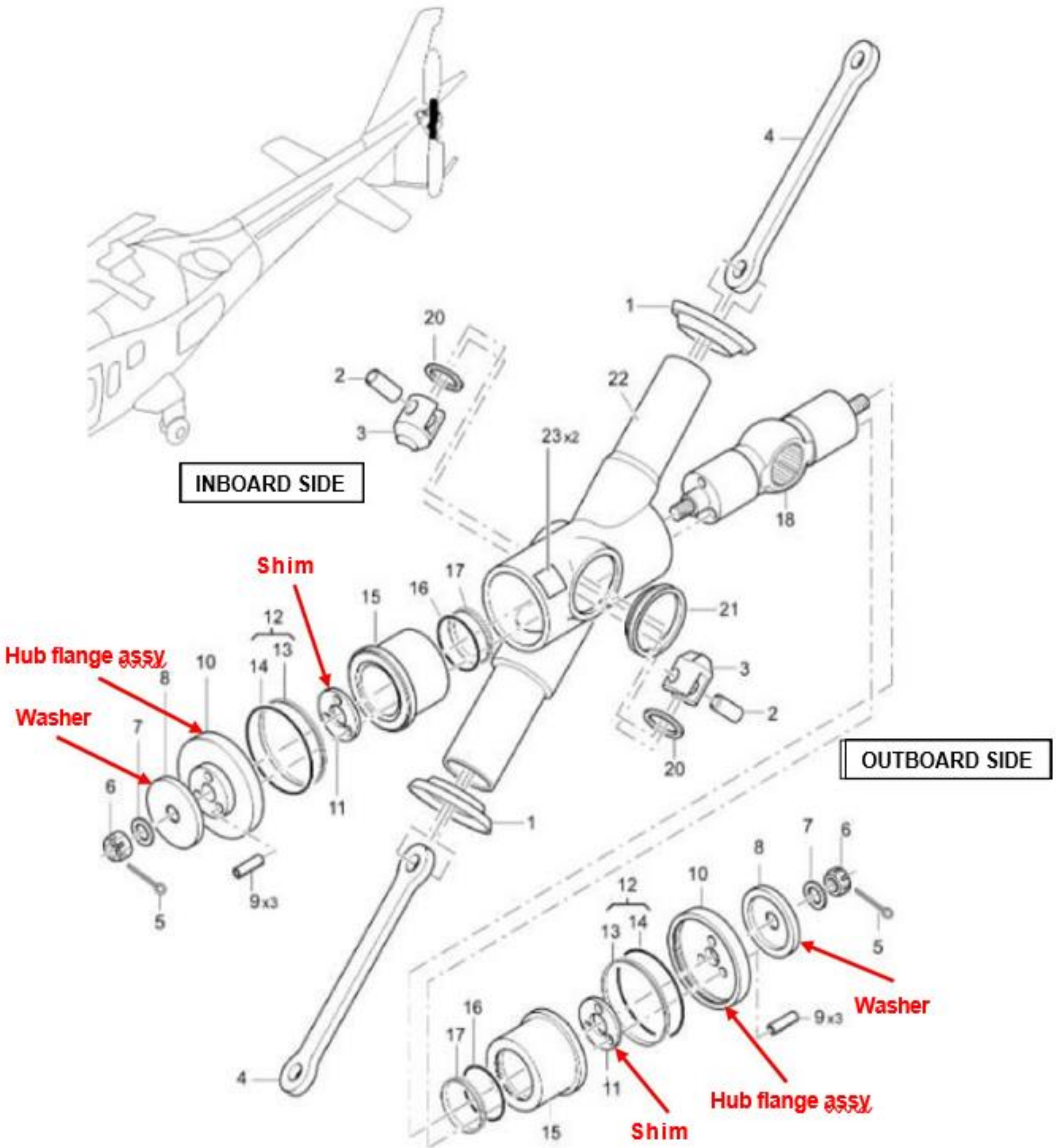


Figure 5 – Exploded view drawing of the tail rotor hub assembly, with indication of the relevant parts for the investigation.

Figure 6 – Details of the two hub flange assemblies, showing the absence of the washers to be installed mating to them (Fig. 6). Instead of the required washer, two thinner and smaller in diameter washers were installed.

Figure 7 – Details of the shims installed under the two hub flange assemblies (Fig. 6). The one under the hub flange with the washer foreseen in the maintenance manual is evidently grinded.

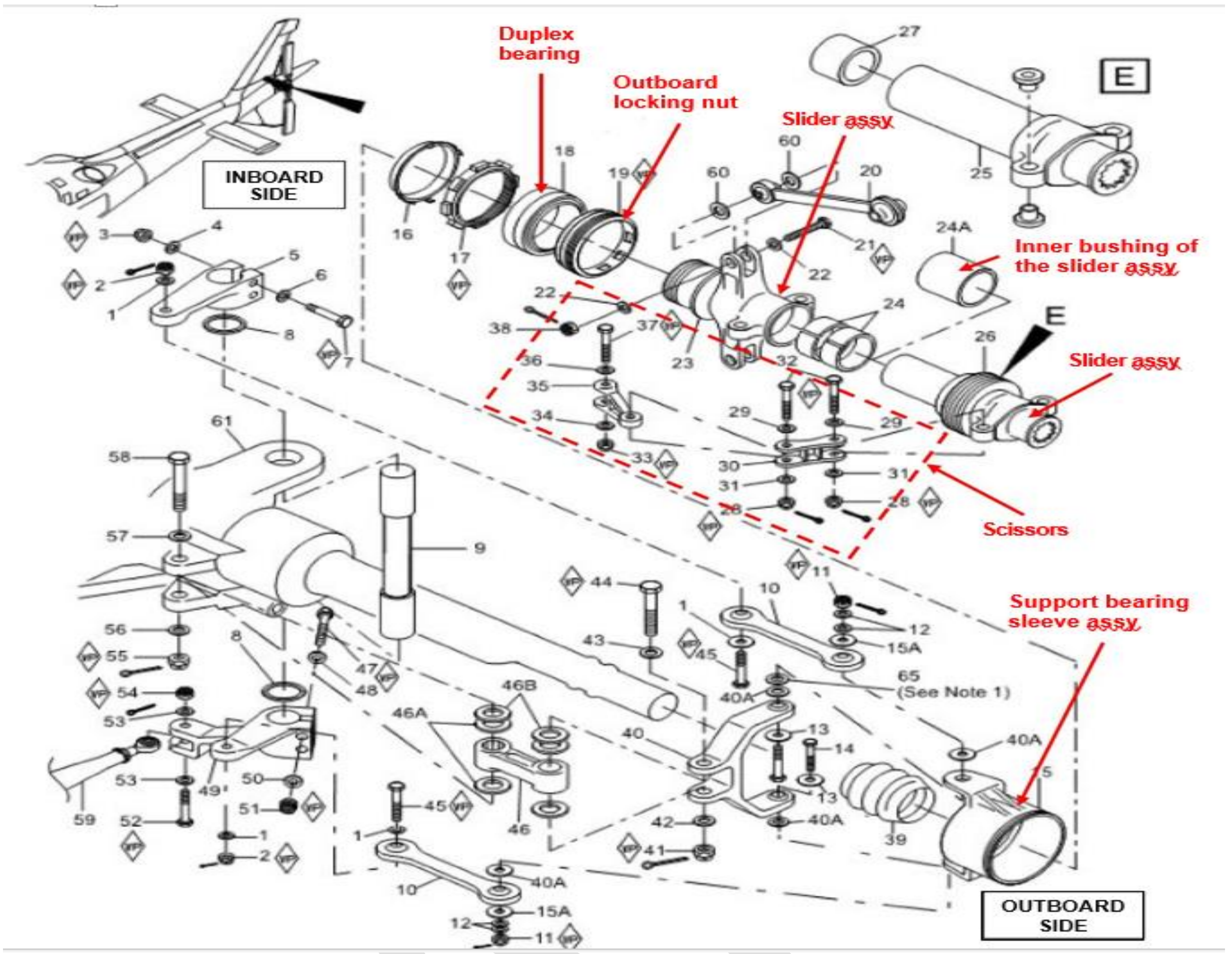


Figure 8 – Exploded view drawing of the tail rotor rotating controls, with indication of the relevant parts for the investigation.

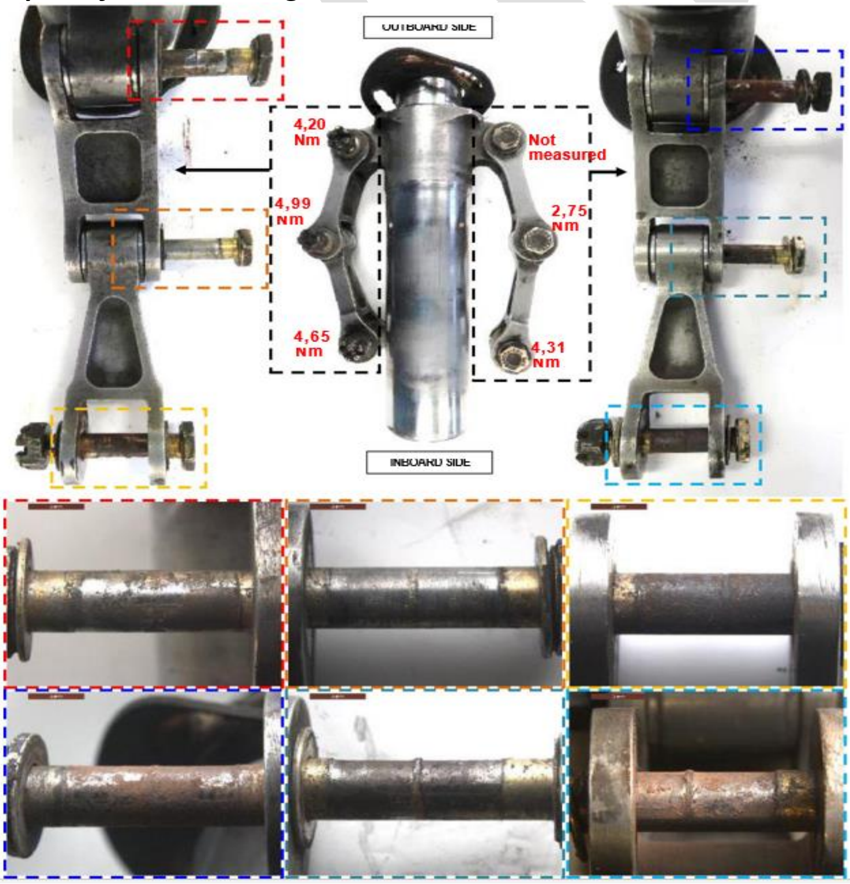


Figure 9 – Details of the worn bolts of the half scissors connecting the slider assembly to the sleeve assembly and measured values of their tightening torque.

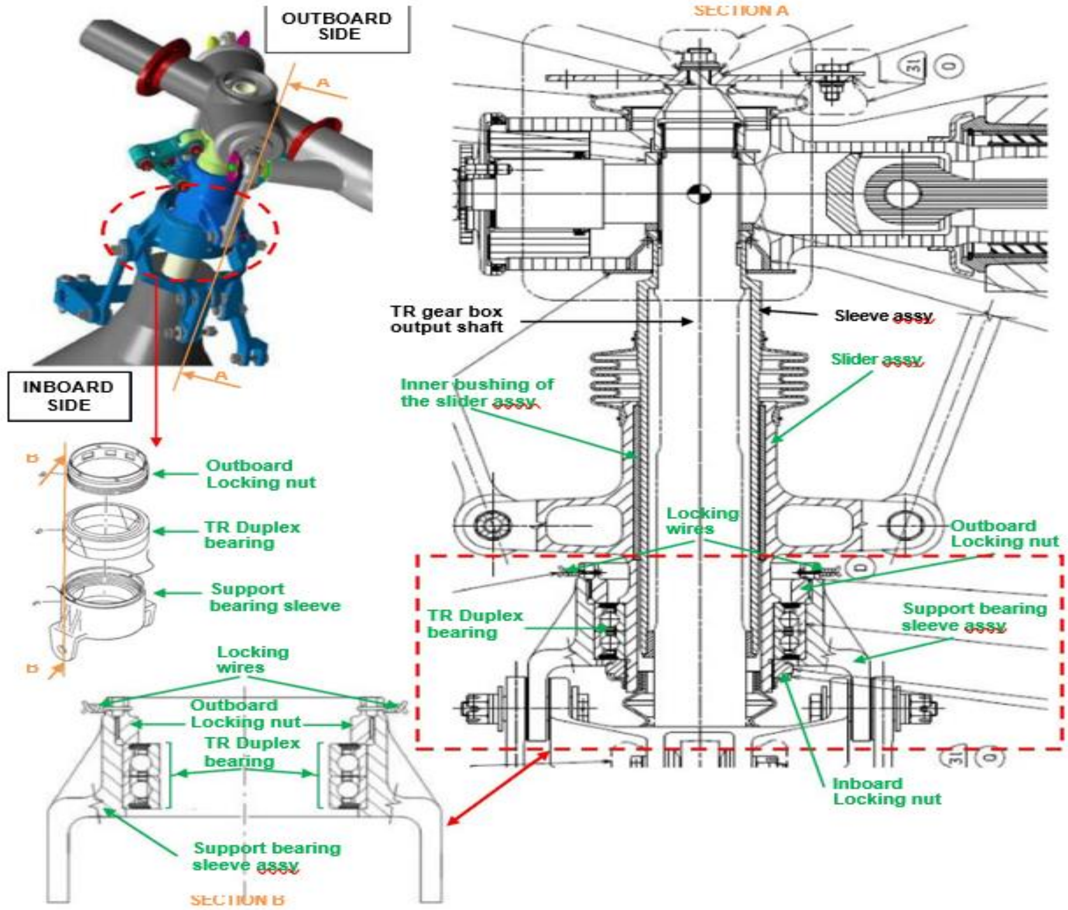


Figure 10 – Drawings of the assembled tail rotor rotating parts, and the assembled support bearing sleeve assembly, duplex bearing and outboard locking nut.

Figure 11 – Details of the worn areas (red circles) with rubbing morphology, observed on the pitch link arms of the slider assembly. The borders of the worn areas correspond to the circumferential edge of the locking nut when in contact to the slider central body.

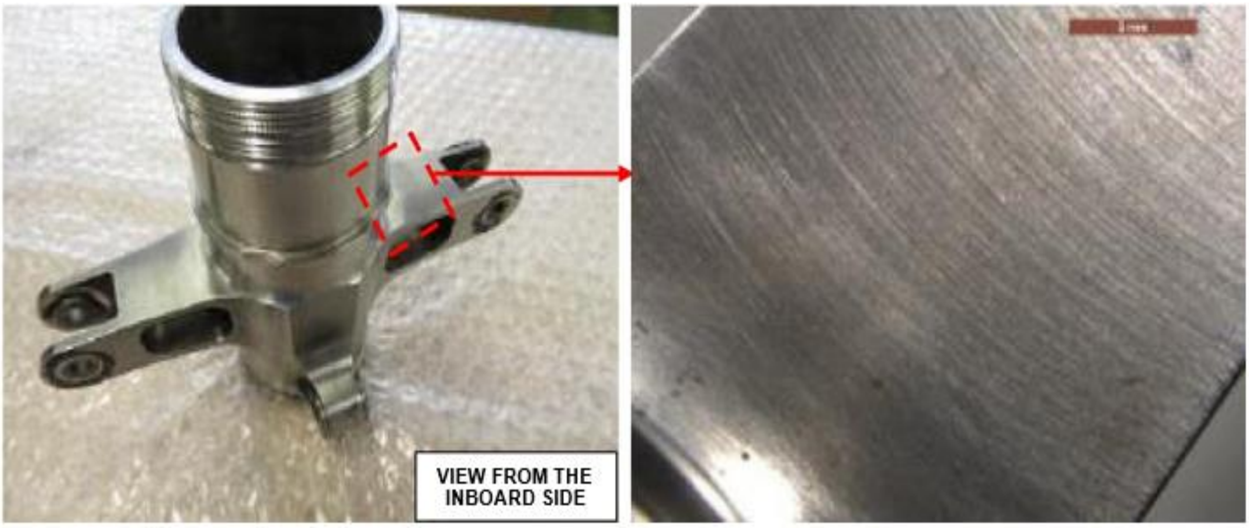


Figure 12 – Details of the pitch link arms of a comparative slider assembly coming from service showing wear areas.

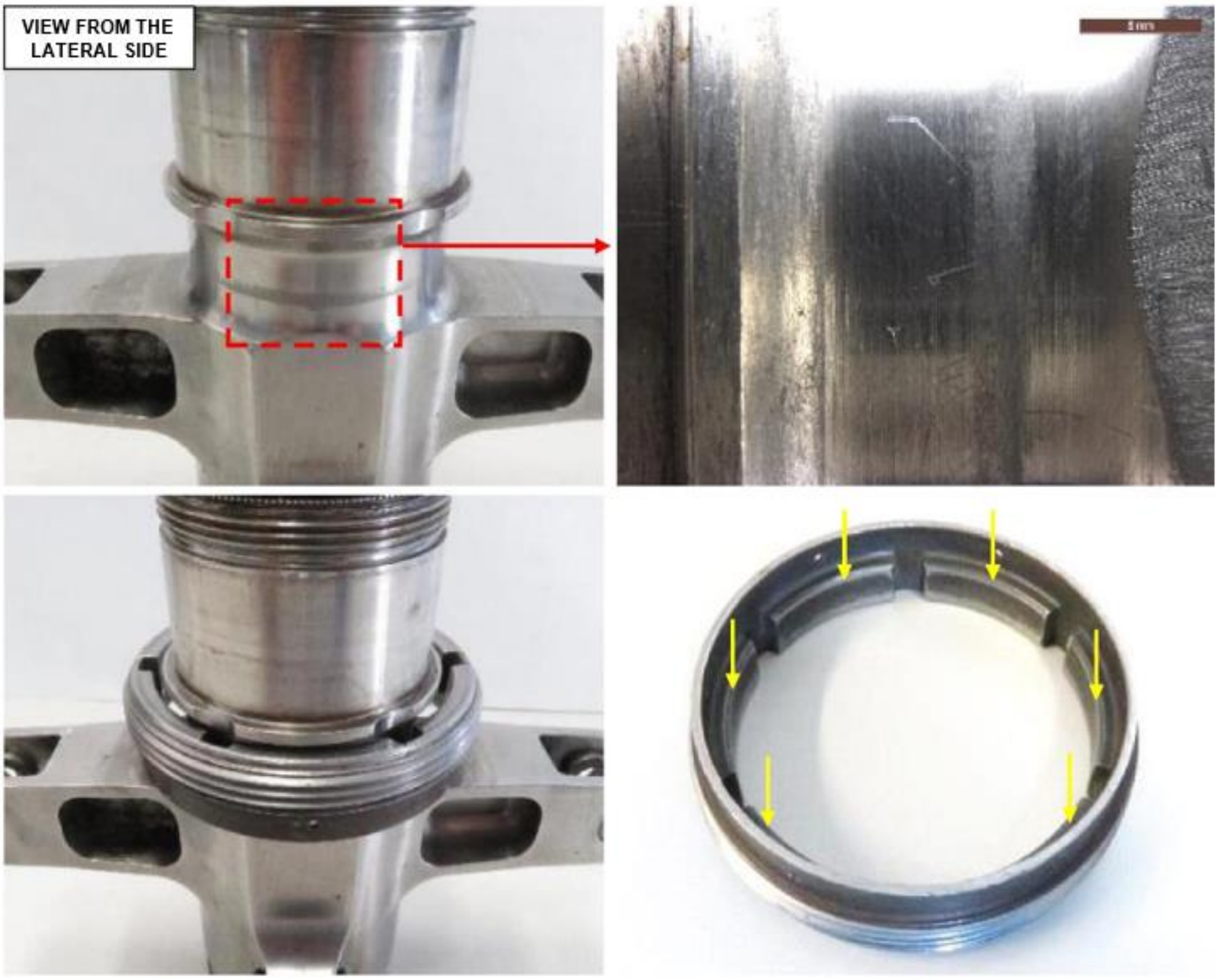


Figure 13 – Details of the circumferential linear marks observed on the lateral surface of the central body of the slider assembly, compatible with the inner surface relief elements of the outboard locking nut (yellow arrows).

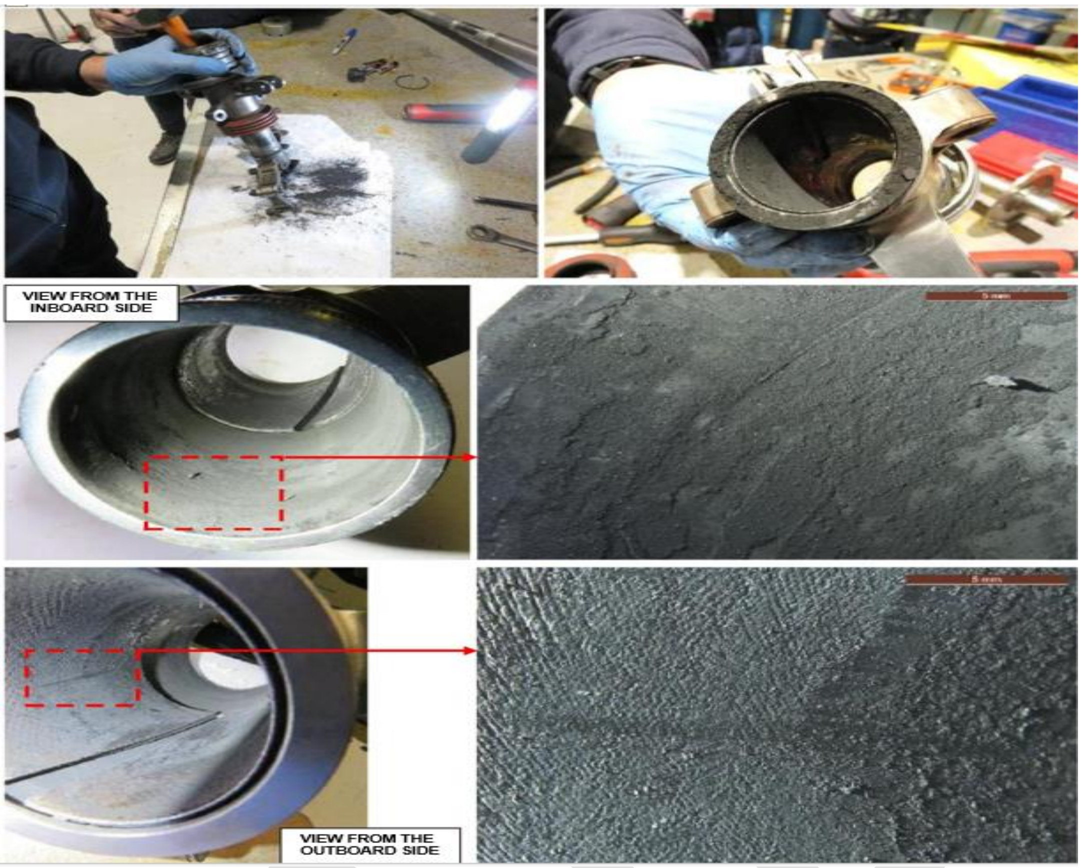


Figure 14 – Details of the slider assembly during the disassembly from the tail rotor and before the cleaning. The inner surface is covered by dark powder from the heavily worn lining of the inner bushing.

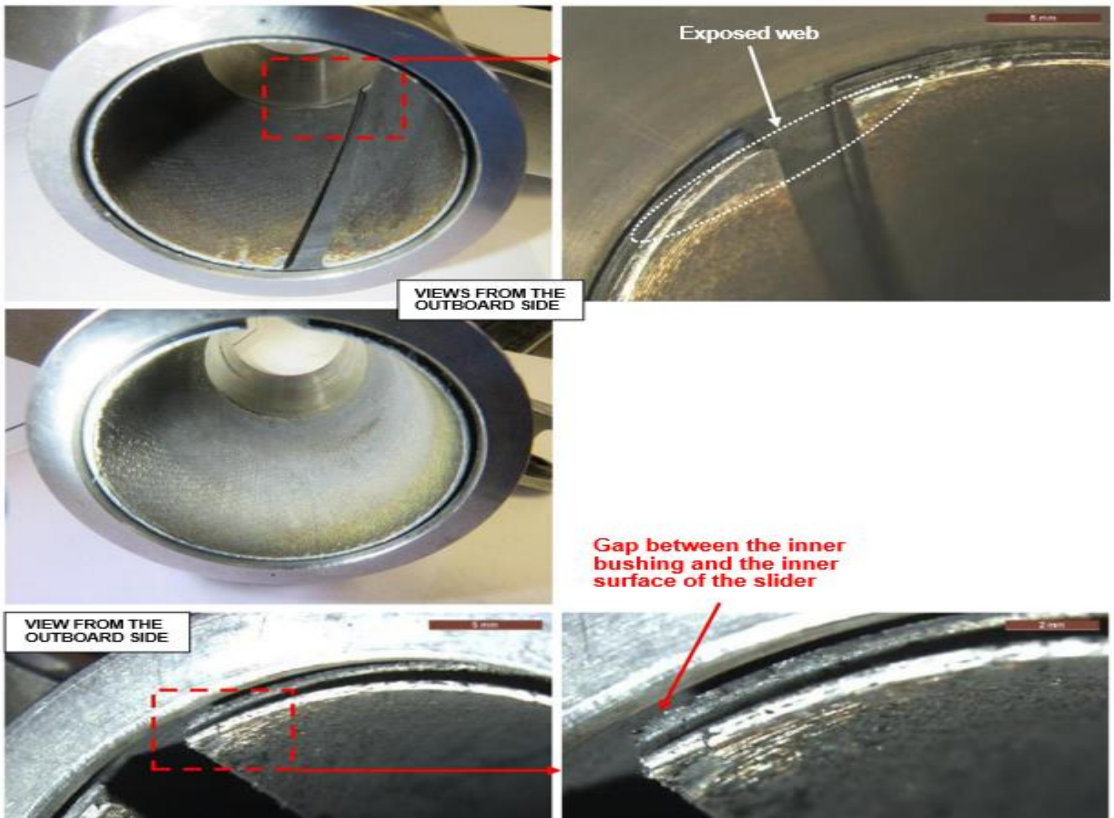


Figure 15 – Details of the slider assembly after the cleaning. The inner bushing is worn and leaves a small portion of the underlying web exposed. Furthermore, the bushing is completely detached from the inner surface.

Figure 16 – Details of the two nearby areas characterized by a multitude of short circumferential nicks, visible on the inner surface of the slider assembly after cleaning.

Figure 17 – Details of the two areas characterized by a multitude of short circumferential nicks visible on the outer surface at the inboard side edge of the sleeve assembly in locations corresponding with those on the slider assembly (Fig. 17)

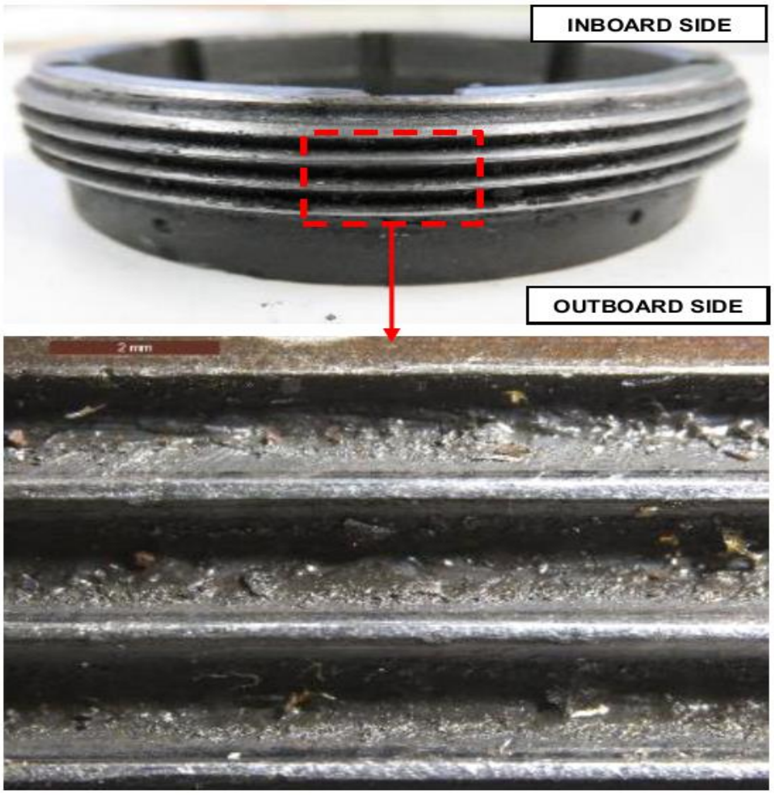


Figure 18 – Details of the outboard locking nut covered by soil-rich duplex bearing grease and missing of the locking wires, as arrived in the laboratory.

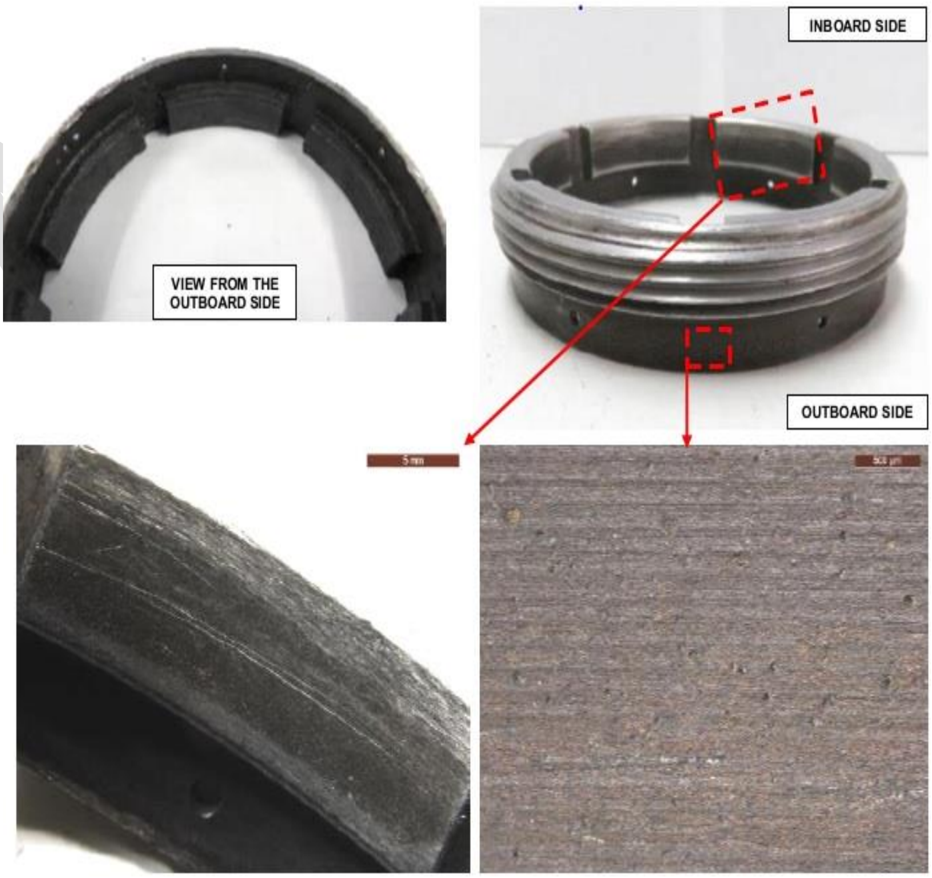


Figure 19 – Details of the outboard locking nut surfaces after cleaning. The nut is almost completely brown in color due to generalized oxidation.

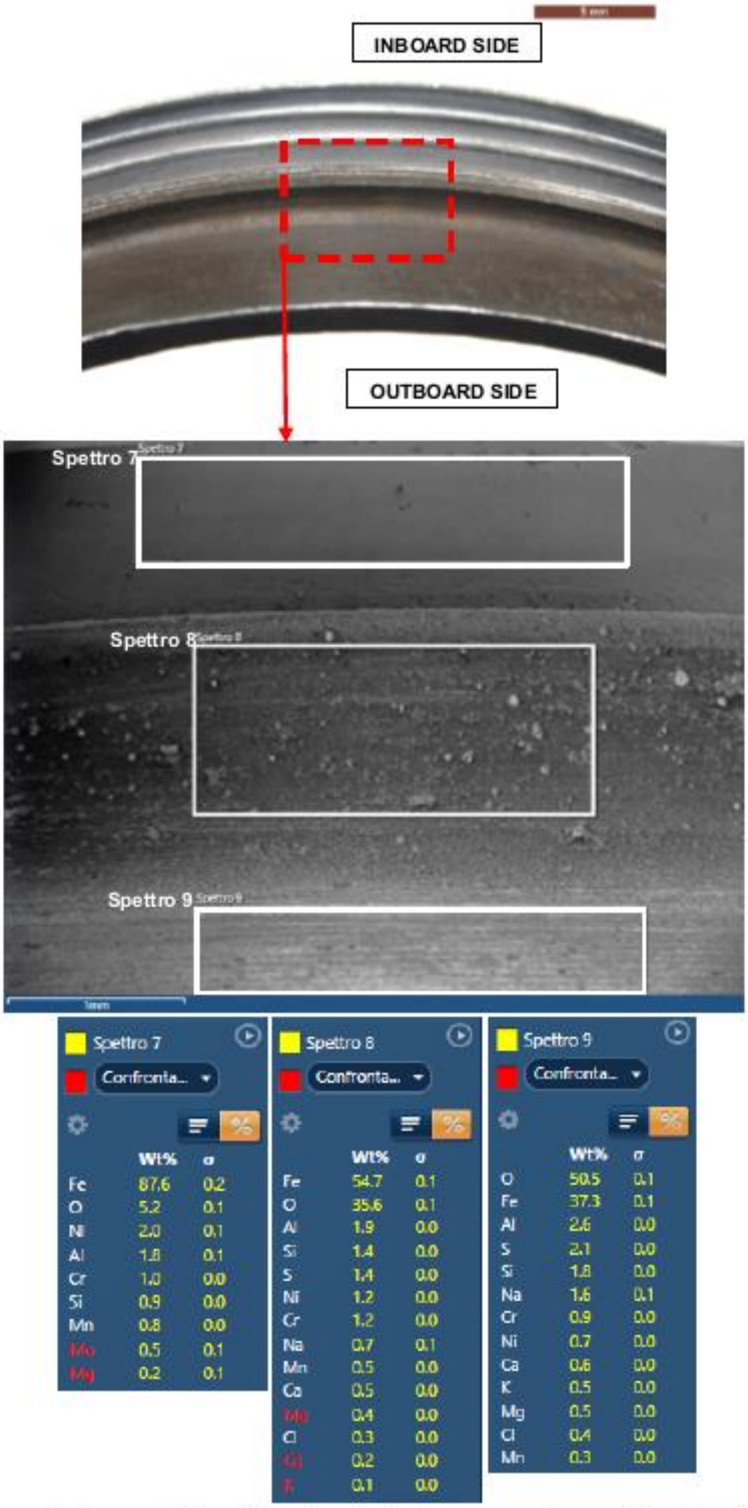


Figure 20 – Semi-quantitative analysis of the chemical elements performed by EDS through the SEM on the outboard locking nut. Cd is almost completely absent in all scanned representative areas of the entire part. The brown areas are rich of O (Spettro 8 and Spettro 9) due to generalized oxidation, while the O amount is considerably lower in the scanned area of the thread (Spettro 7), which kept the color of the steel. All other detected elements belong to the nut steel alloy, the soil and the tail rotor parts with which the nut has come in contact in the event.

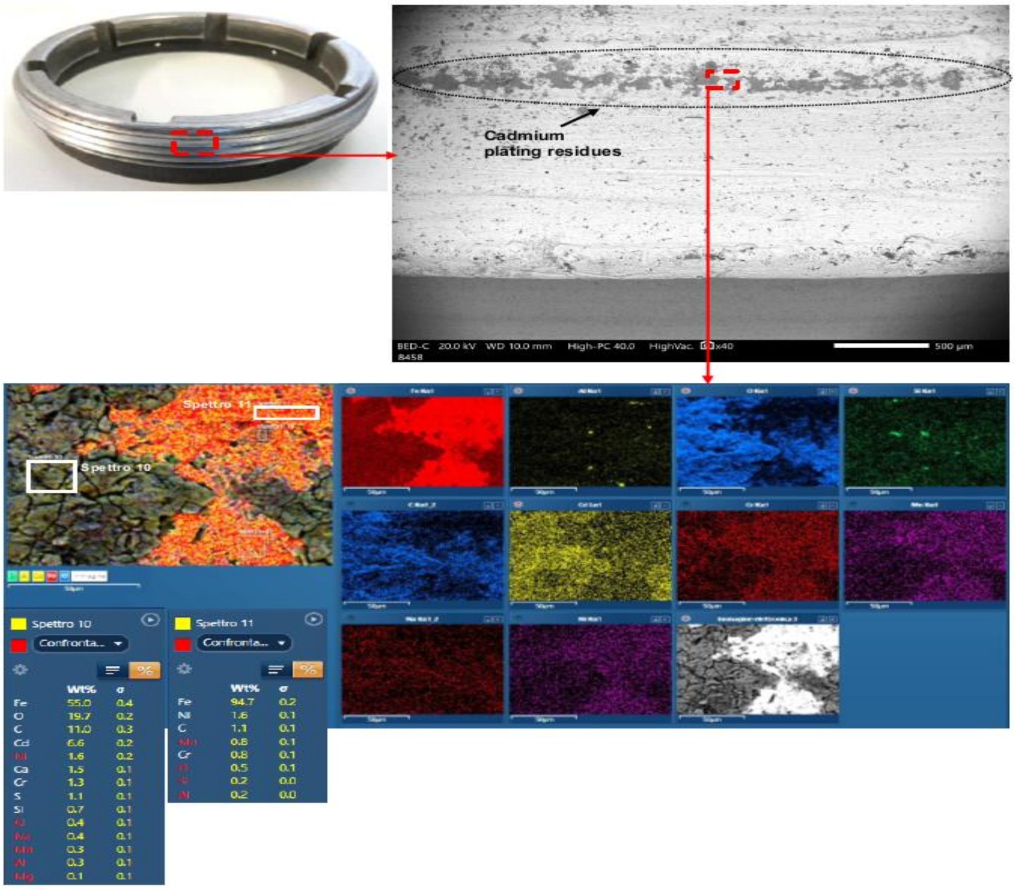


Figure 21 – Map (in each window the distribution of a specific chemical element in the scanned area is reported) and semi-quantitative analysis of the chemical elements performed by EDS through the SEM on an area of the outboard locking nut characterized by a residue of cadmium plating mixed with elements belonging to the soil and the tail rotor parts with which the nut has come in contact in the event (Spettro 10). Some of these elements have also been detected in the areas free of cadmium plating, characterized by the elements belonging to the nut steel alloy (Spettro 11)

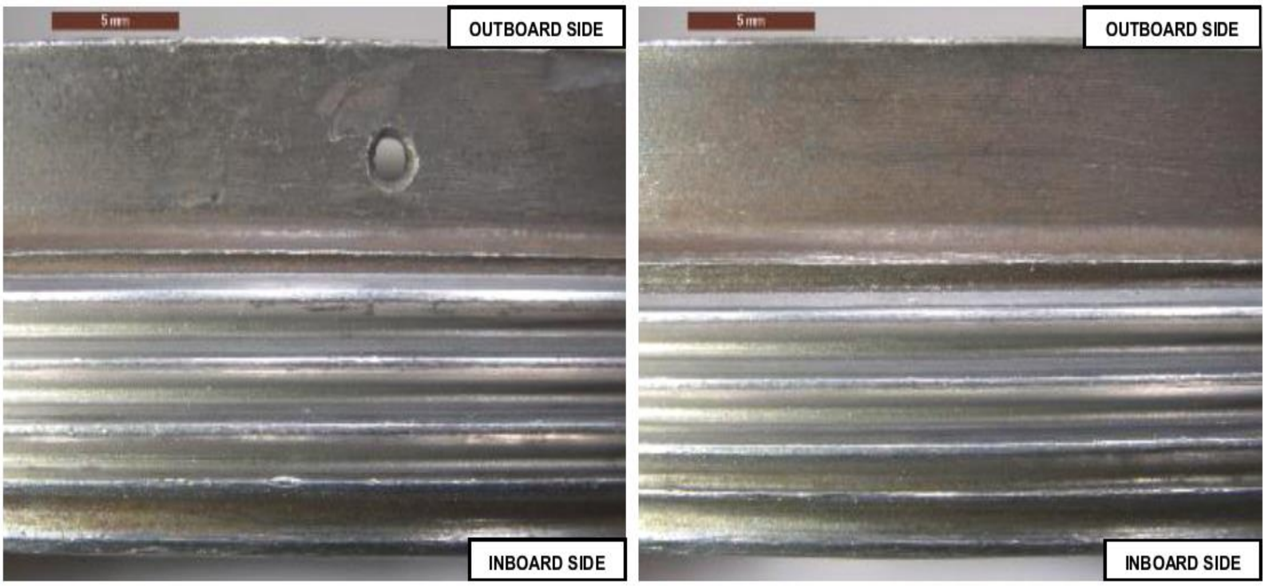


Figure 22 – Details of the outboard locking nut thread free of thread locking adhesive (Loctite® 222)

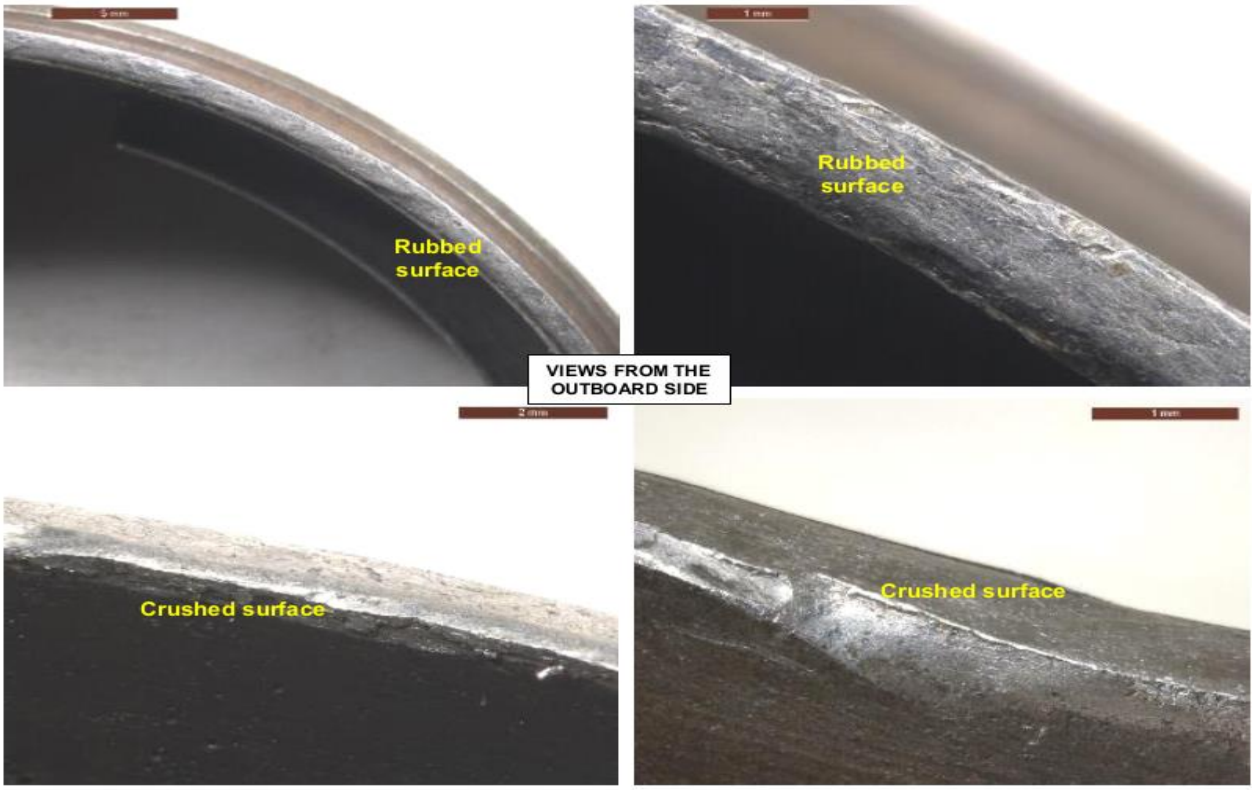


Figure 23 – Details of the rubbed and crushed outboard circumferential surface of the outboard locking nut

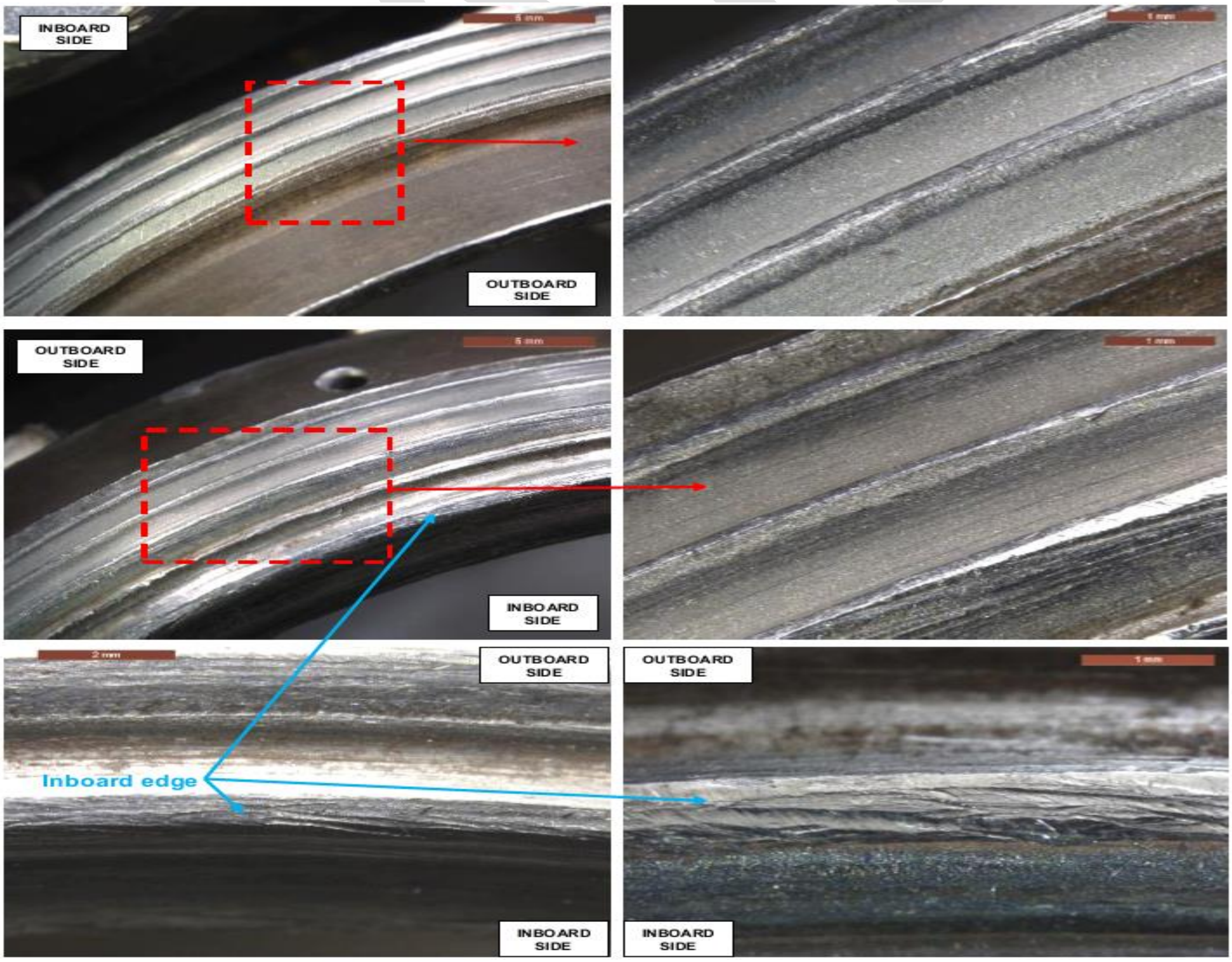


Figure 24 – Details of the outboard locking nut threads, which do not show relevant damages. Crushed areas and oblique nicks are visible only on the two threads towards the inboard side and particularly on the inboard side edge of the nut.

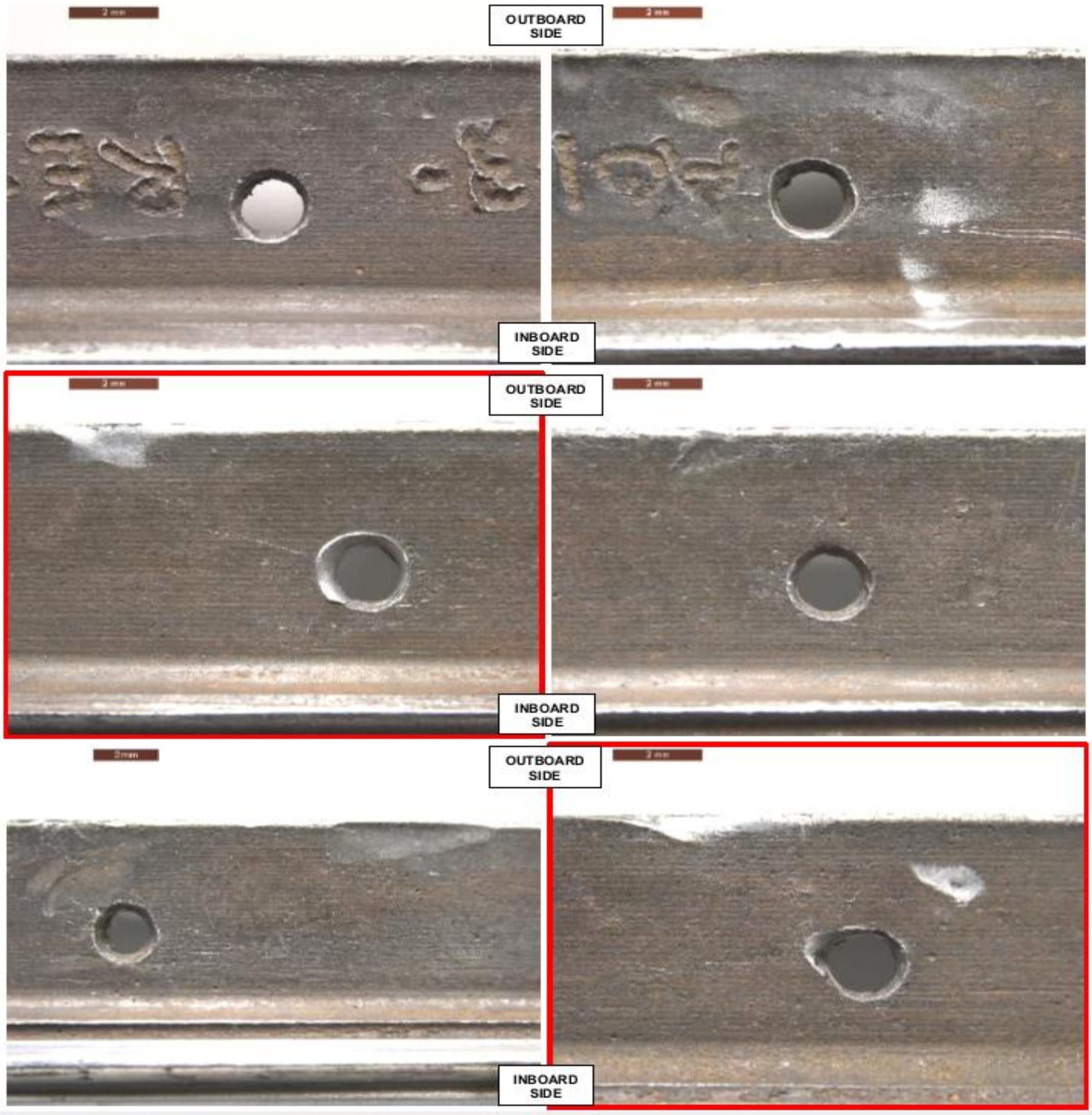


Figure 25 – Details of the outboard locking nut holes for fixing the locking wires, observed from the outer side. All holes edges and the corresponding areas of the nut outboard edge are worn, indicating they have been used in the various tail rotor installations. All the worn areas are brown in color due to the generalized oxidation, with the exception of two holes (red rectangles), which were probably used in the last installation.

Figure 26 – Details of the support bearing sleeve assembly with inner surface covered by soil-rich duplex bearing grease and missiFng of the locking wires, as arrived in the laboratory.

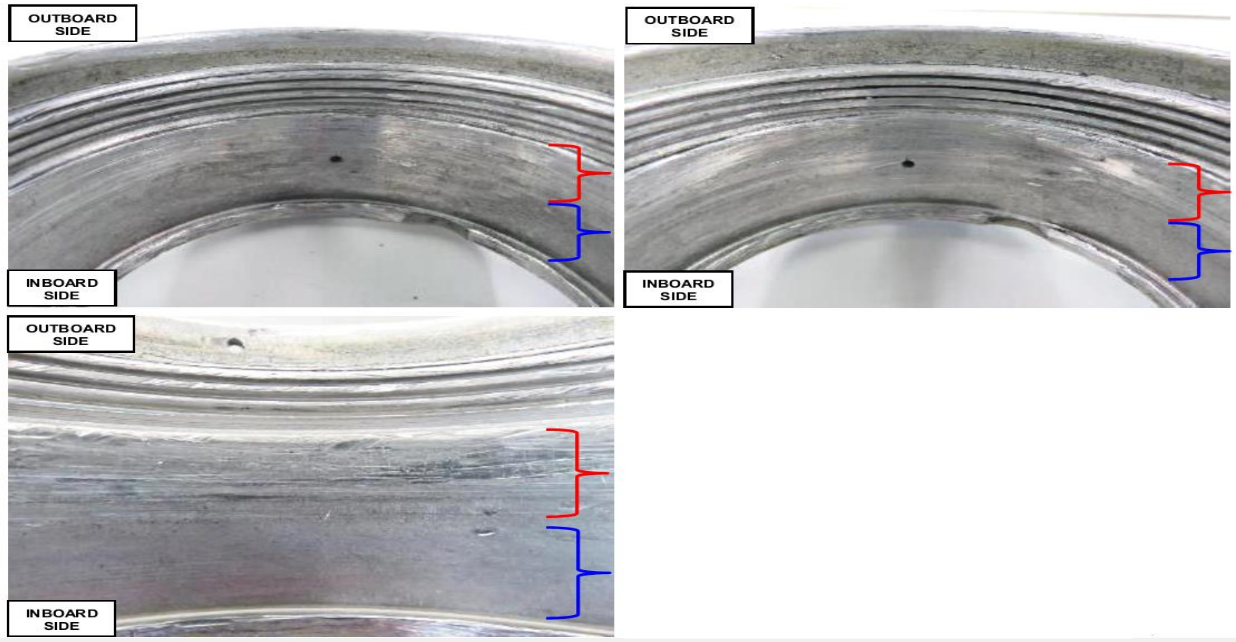


Figure 27 – Details of the support bearing sleeve assembly inner surface after cleaning. The threads and the duplex bearing seat completely lost the yellowish color of the chromate conversion treatment required by the drawing. The inboard bearing seat (blue parentheses) shows no significant damages, while the outboard bearing seat (red parentheses) is characterized by a multitude of circumferential marks and deep inclined nicks. The nicks are also visible on the thread. These marks and nicks are showed in detail in Fig. 30.

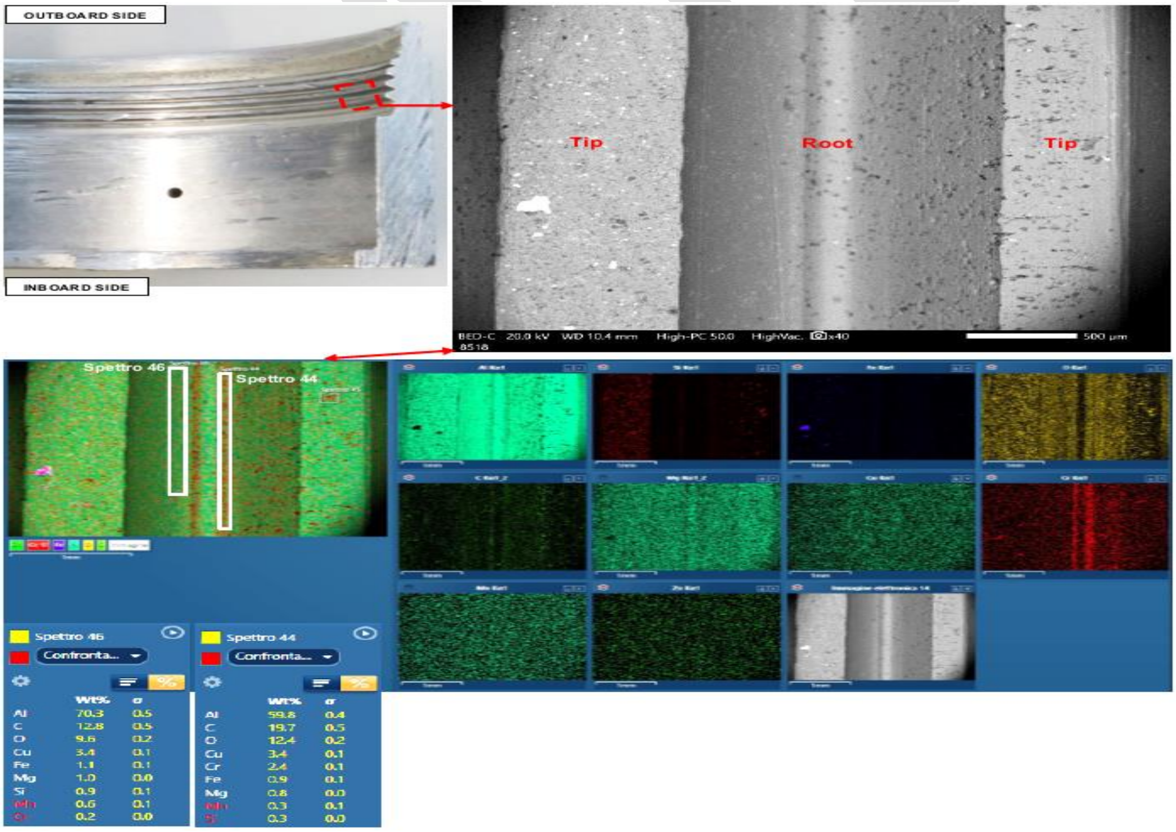


Figure 28 – Map (in each window the distribution of a specific chemical element in the scanned area is reported) and semi-quantitative analysis of the chemical elements performed by EDS through the SEM on a representative area of the support bearing sleeve assembly thread. Cr is almost completely absent (Spettro 46). A more considerable amount was only detected in the roots of the threads (Spettro 44) being more protected from possible manipulations. All other detected elements belong to the support bearing aluminum alloy and the tail rotor parts with which the support bearing has come in contact in the event.

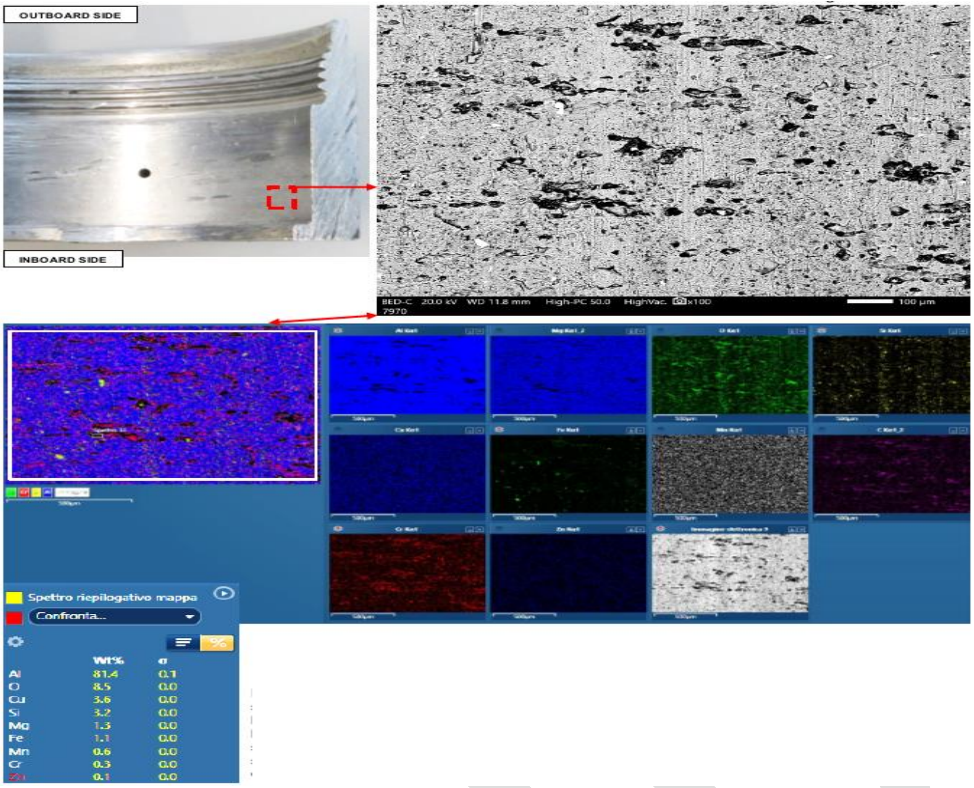


Figure 29 – Map (in each window the distribution of a specific chemical element in the scanned area is reported) and semi-quantitative analysis of the chemical elements performed by EDS through the SEM on a representative area of the inboard bearing seat of the support bearing sleeve assembly. Cr is almost completely absent (the spectrum is related to the entire scanned area surrounded by the white rectangle). All other detected elements belong to the support bearing aluminum alloy and the tail rotor parts with which the support bearing has come in contact in the event.

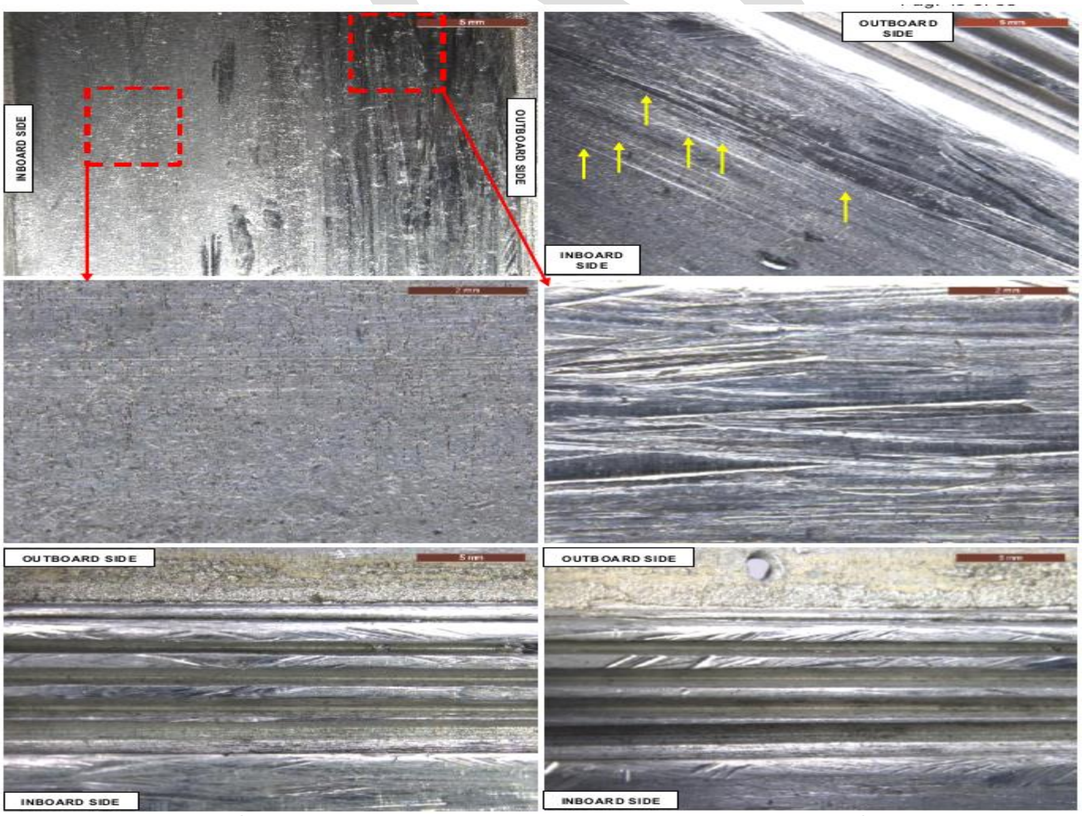


Figure 30 – Details of the support bearing sleeve assembly inner surface. The threads and the duplex bearing seat completely lost the yellowish color of the chromate conversion treatment required by the drawing. The inboard bearing seat shows no significant damages, while the outboard bearing seat is characterized by a multitude of circumferential marks (yellow arrows) and deep inclined nicks. The nicks are also visible on the thread.

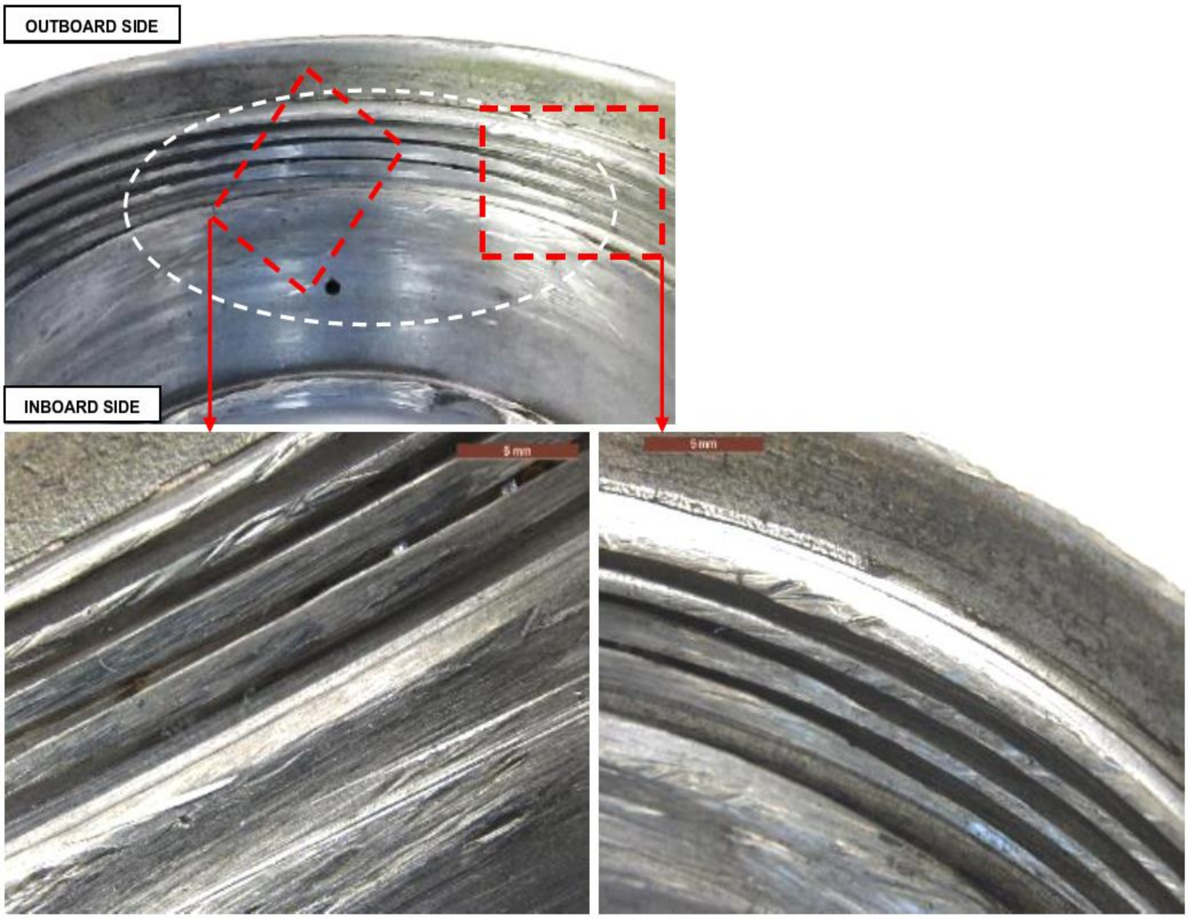


Figure 31 – Detail of the significant crushed localized area involving the outboard bearing seat and the thread adjacent to it (white ellipse).

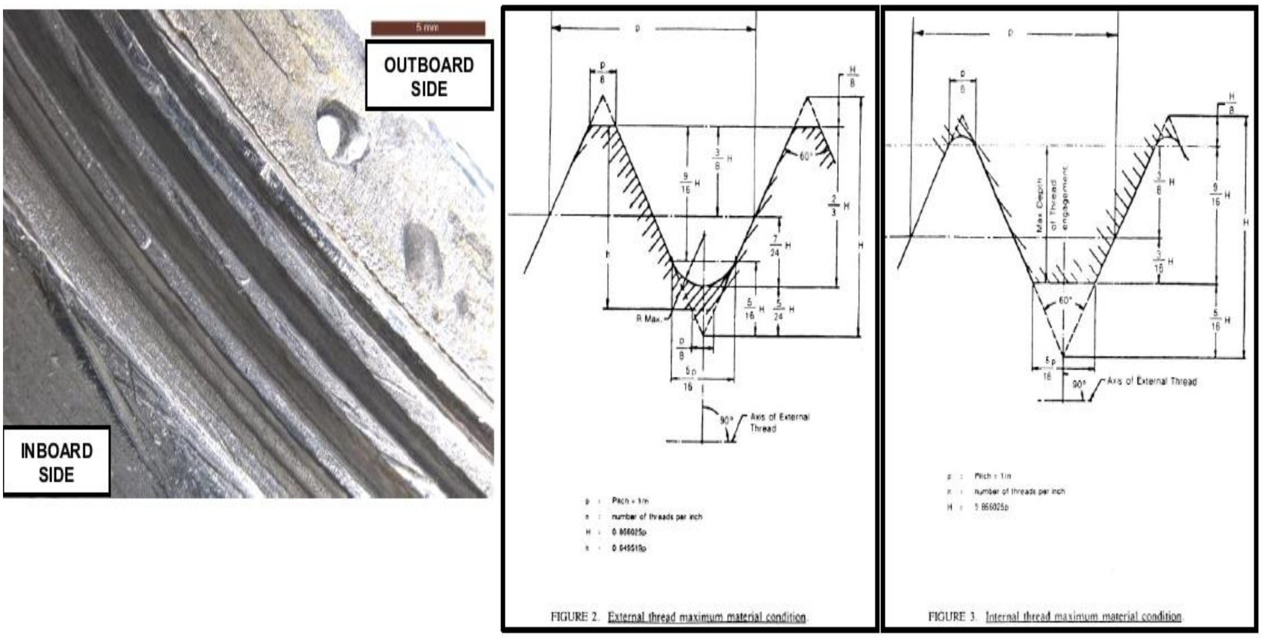


Figure 32 – Detail of the overall intact support bearing sleeve assembly thread, which maintained the trapezoidal profile required by the drawing and excerpt of MIL-S-8879 specification which it refers to.

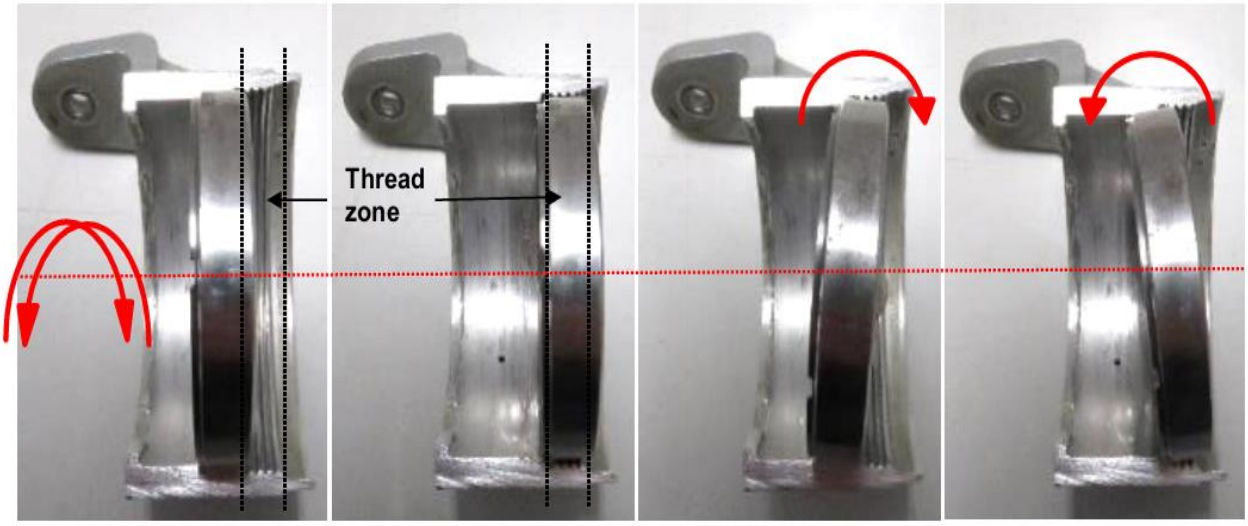


Figure 33 – Representation of the probable positions assumed by the outboard bearing outer ring as it rotated and tilted during the event, impacting / slipping with the inner surface of the support bearing sleeve assembly.

Figure 34 – Details of some crushed areas and inclined nicks visible on the outboard edge of the support bearing sleeve assembly (red arrows), due to the contact with the outboard locking nut after unscrewing.

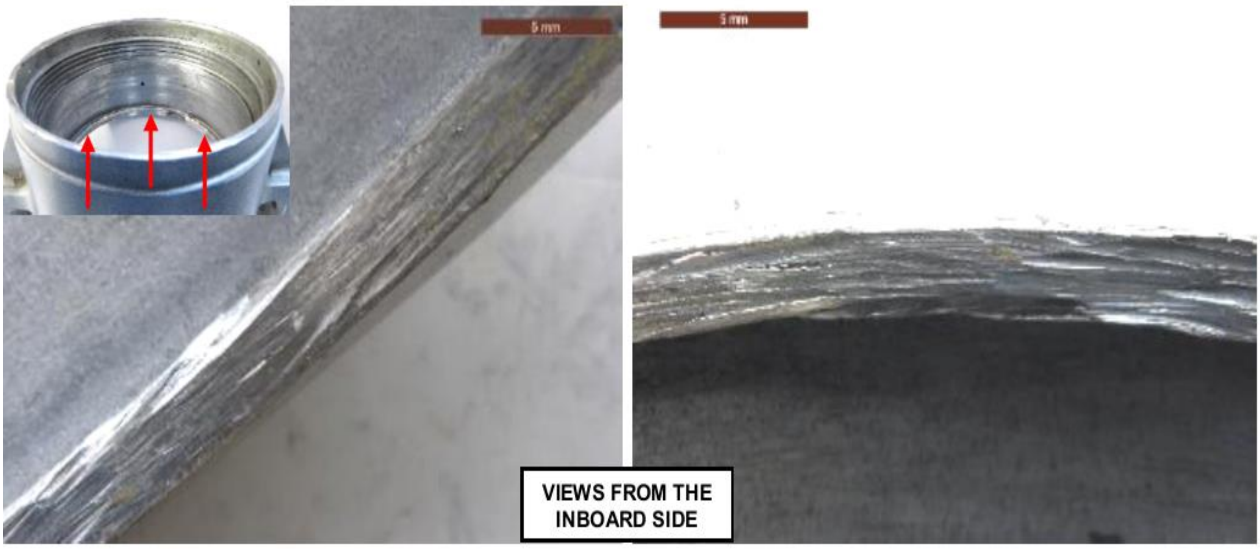


Figure 35 – Details of some nicks visible on the side surface of the shoulder of the support bearing sleeve assembly mating with the inboard bearing (red arrows), due to the contact with the relief elements of the inboard locking nut.

Figure 36 – Details of the crushed areas and inclined nicks visible on the relief elements of the inboard locking nut, due to the contact with the shoulder of the support bearing sleeve assembly mating with the inboard bearing.

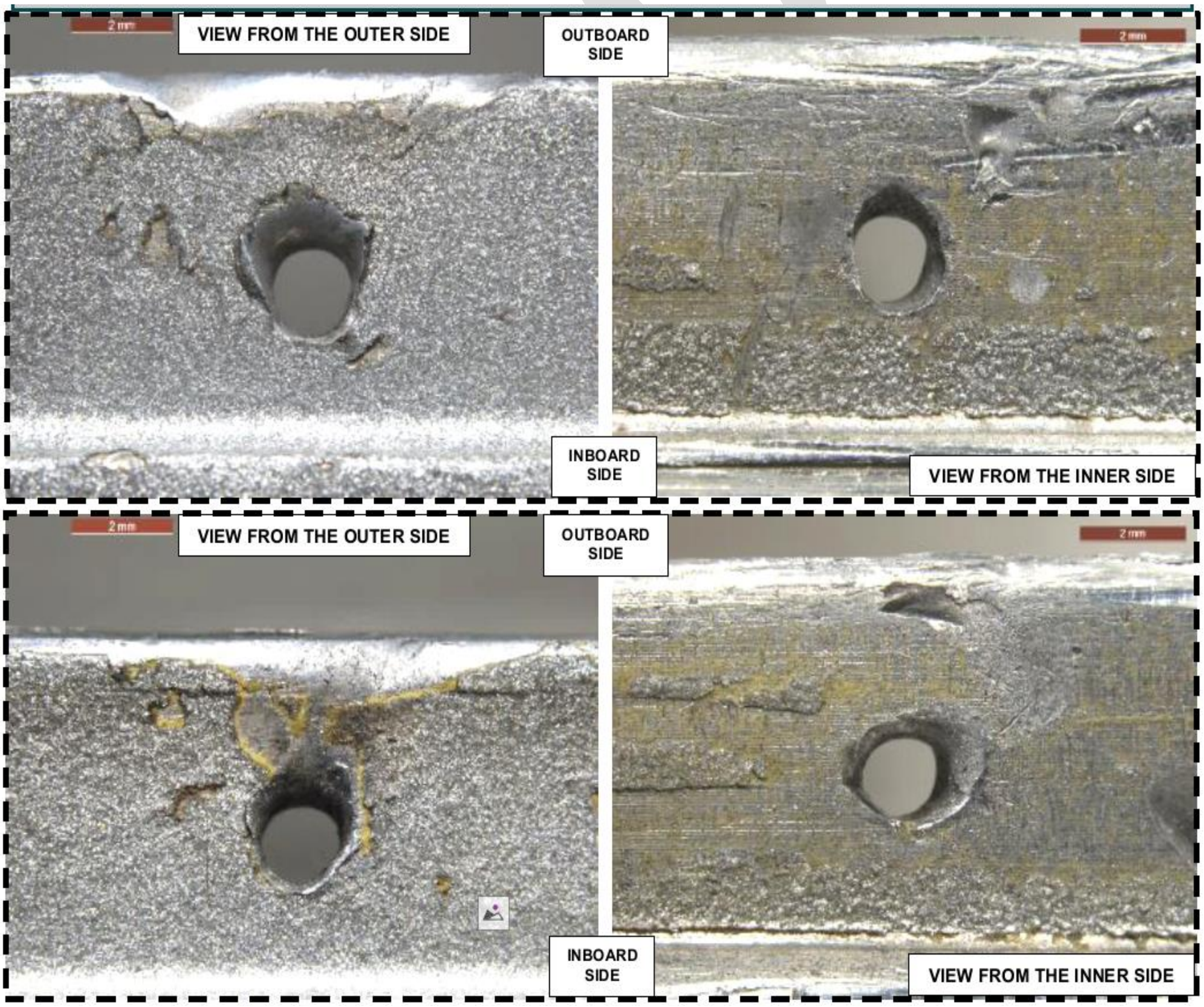


Figure 37 – Details of the large worn areas visible at the edges of the support bearing sleeve assembly holes for fixing the locking wires, at their sides and at the support bearing outboard edge.

Figure 38 – Details of the duplex bearing as arrived in the laboratory. The outer rings were separated from the inner ones.

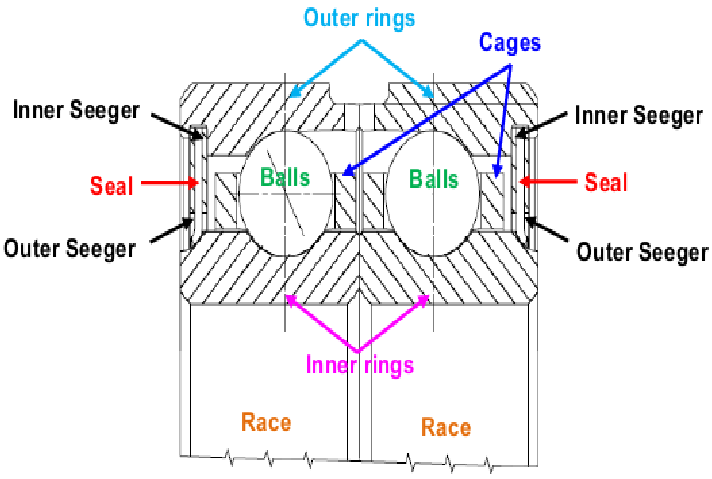


Figure 39 – Drawing of the duplex bearing section, showing all its parts.

Figure 40 – Details of the duplex bearing outer rings with inner surface covered by soil-rich grease, as arrived in the laboratory.

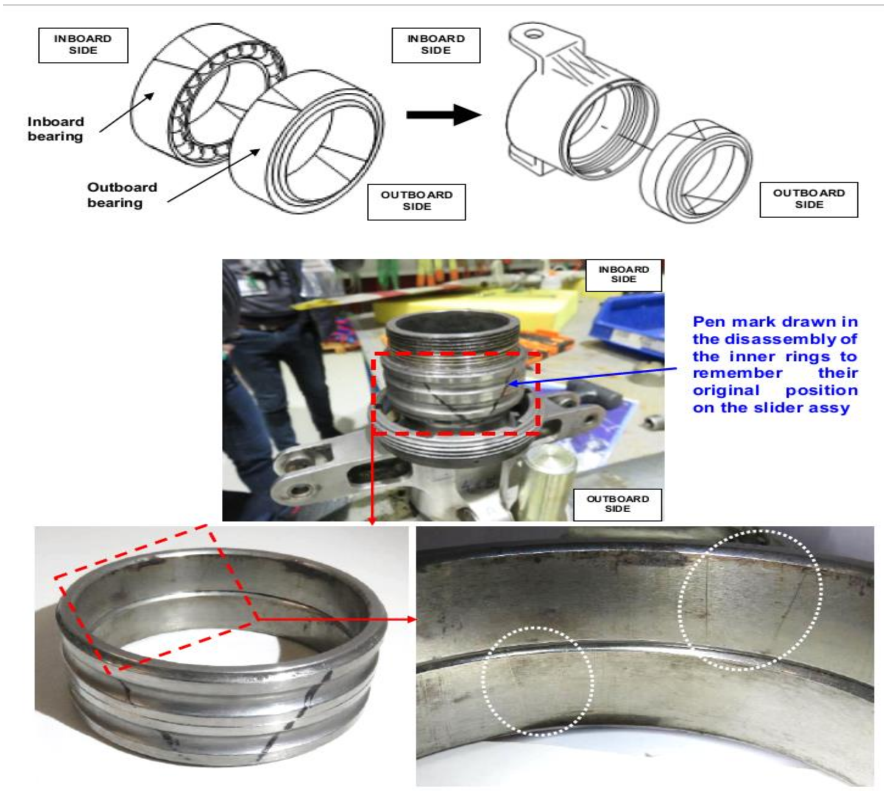


Figure 41 – Scheme of the duplex bearing assembly and its installation in the support bearing sleeve assembly and details of the engravings on the duplex bearing inner rings (white ellipsis), which were correctly oriented but not aligned with each other to form the V-shaped mark.

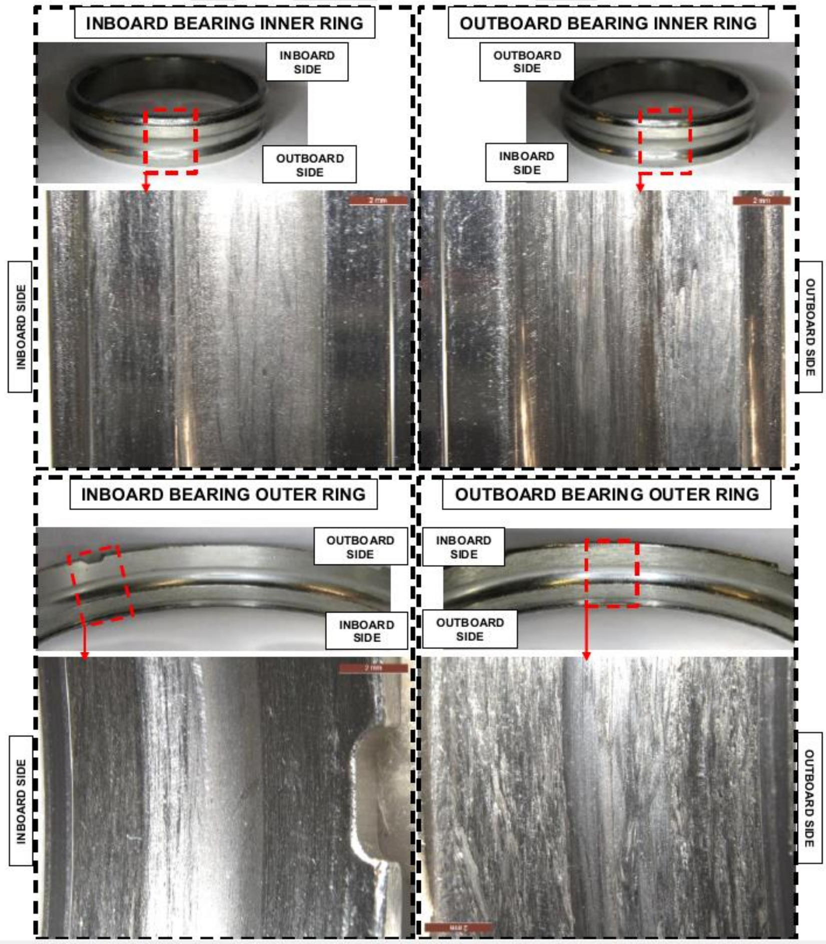


Figure 42 – Details of the multitude of impact / slipping marks visible on the races and the surface of the shoulders at their two sides of all rings. The outboard bearing outer ring is particularly damaged.

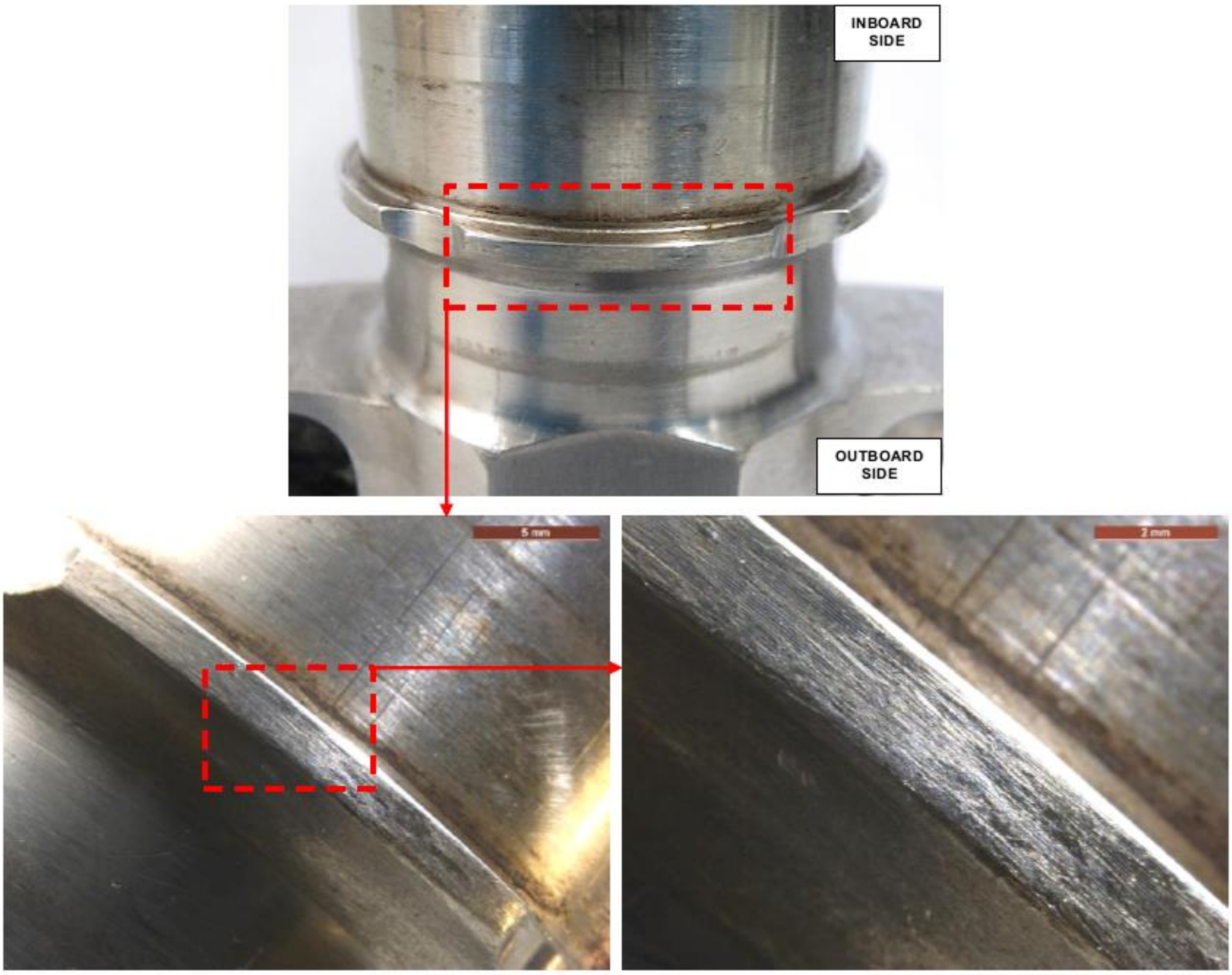


Figure 43 – Details of the multitude of impact / slipping marks visible on the raised elements of the slider assembly.

APPENDIX 'C'

GRAPHICAL REPRESENTATION OF PARAMETERS WITH FDR TIME FOR ACCIDENT FLIGHT

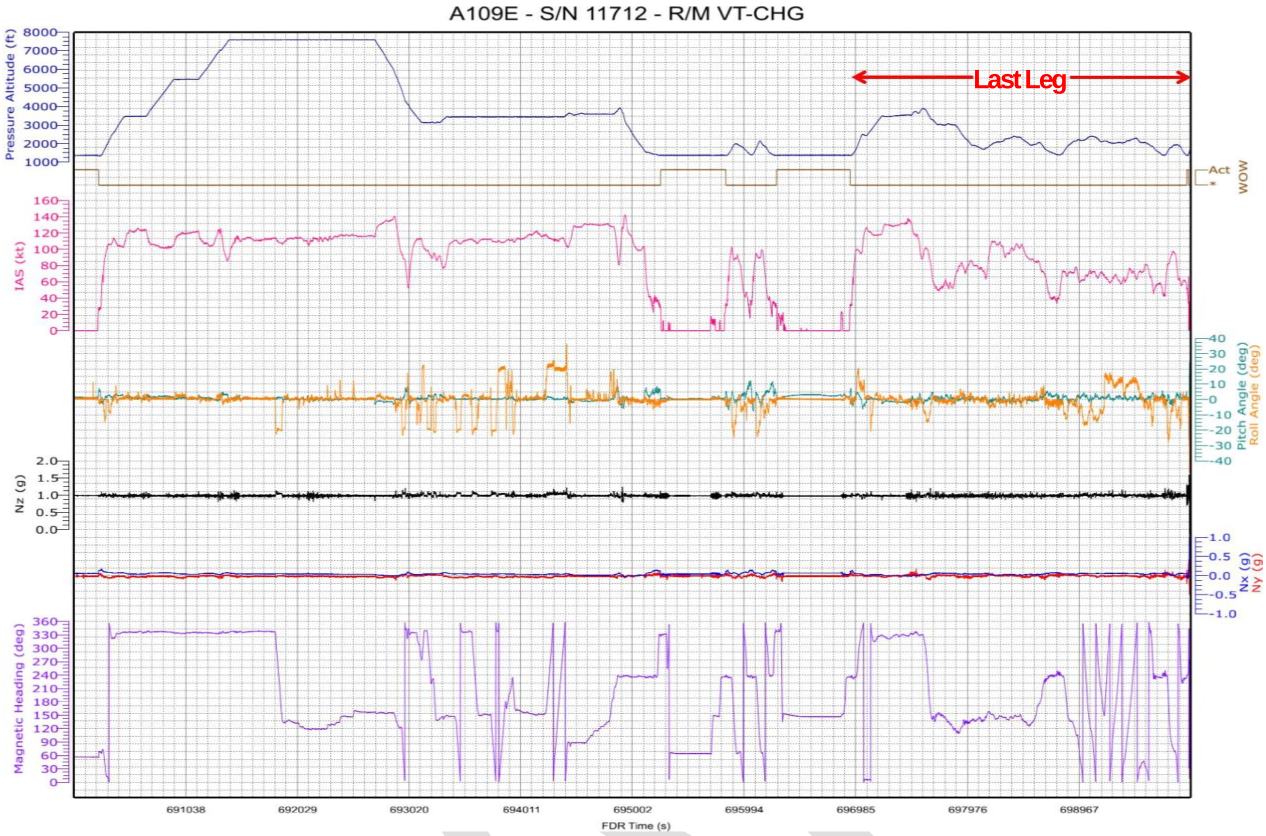


Figure 1. Flight path data for the whole final flight

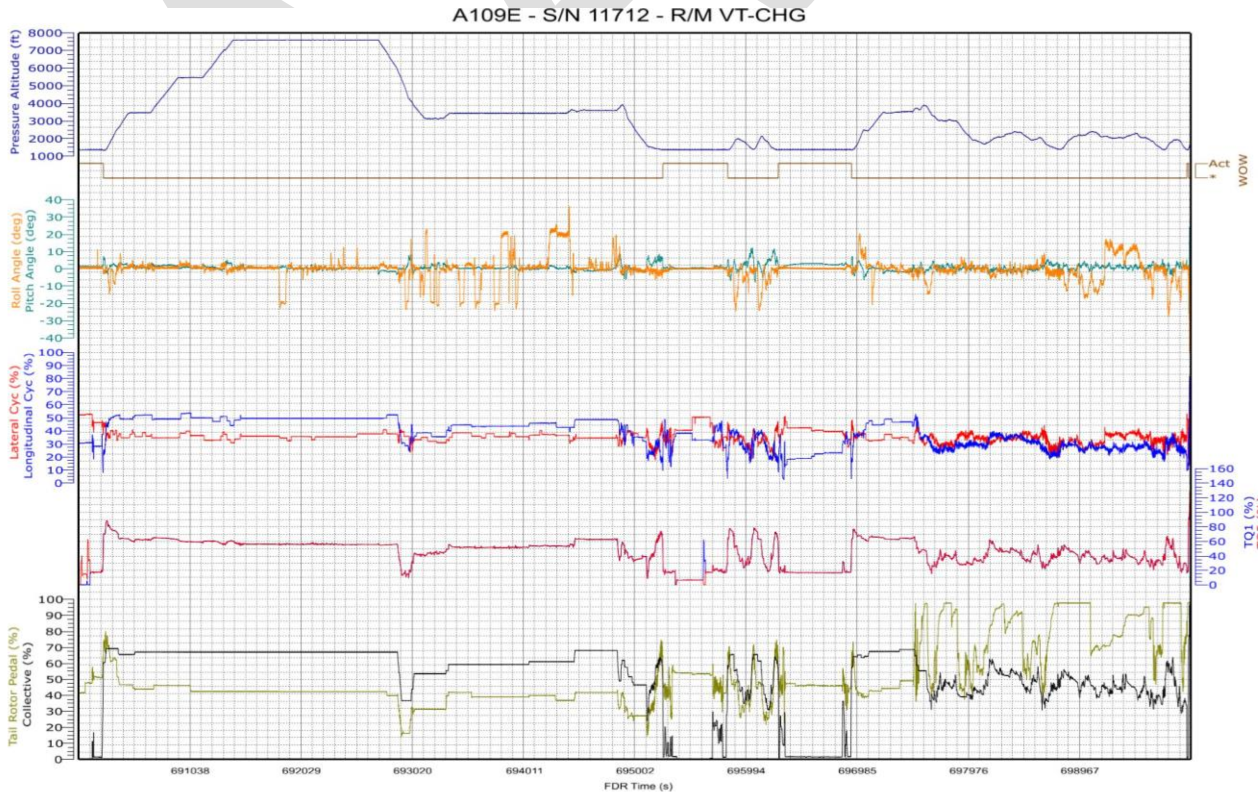


Figure 2. Flight controls data for the whole final flight

Figure 3. Power Plant Data for the whole final flight

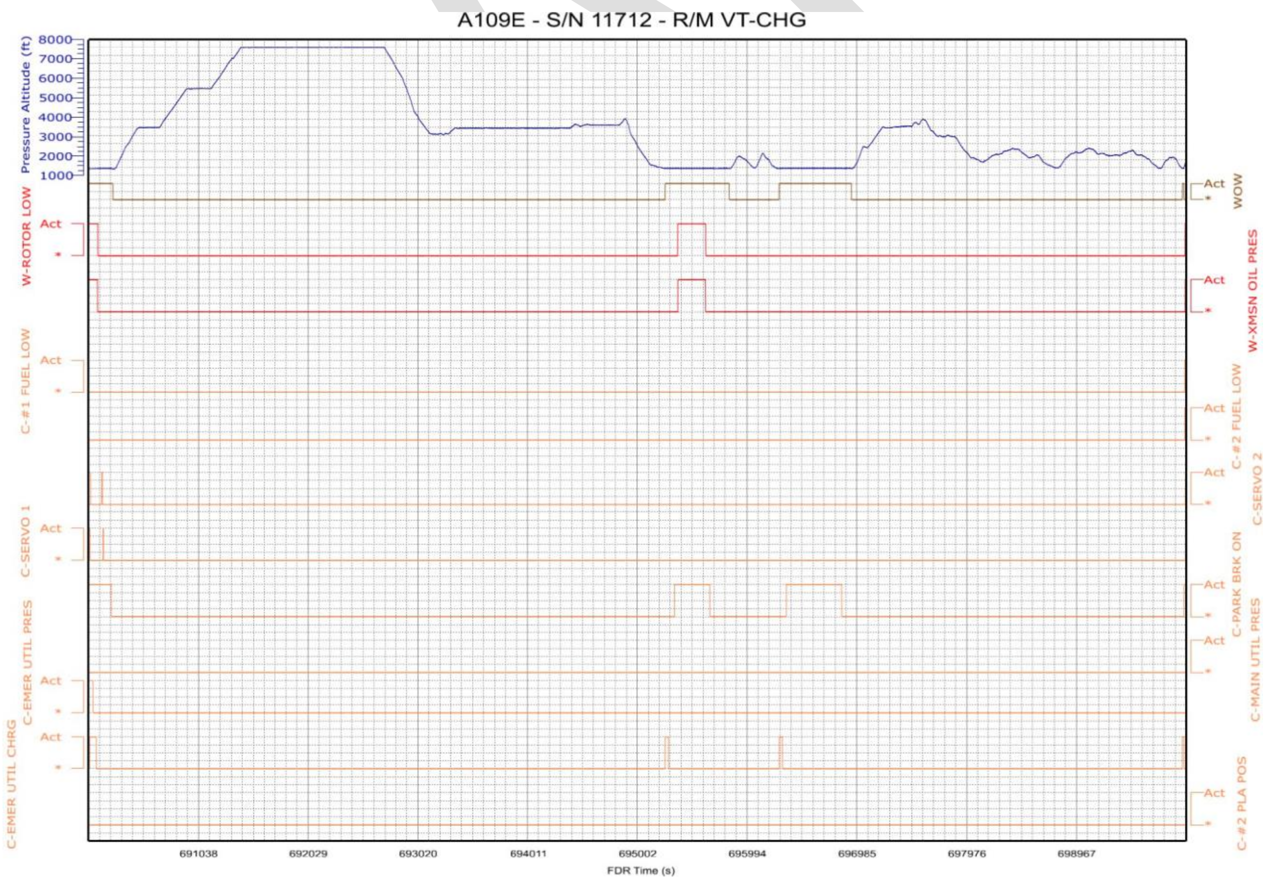


Figure 4. Cautions & Warnings for the whole final flight

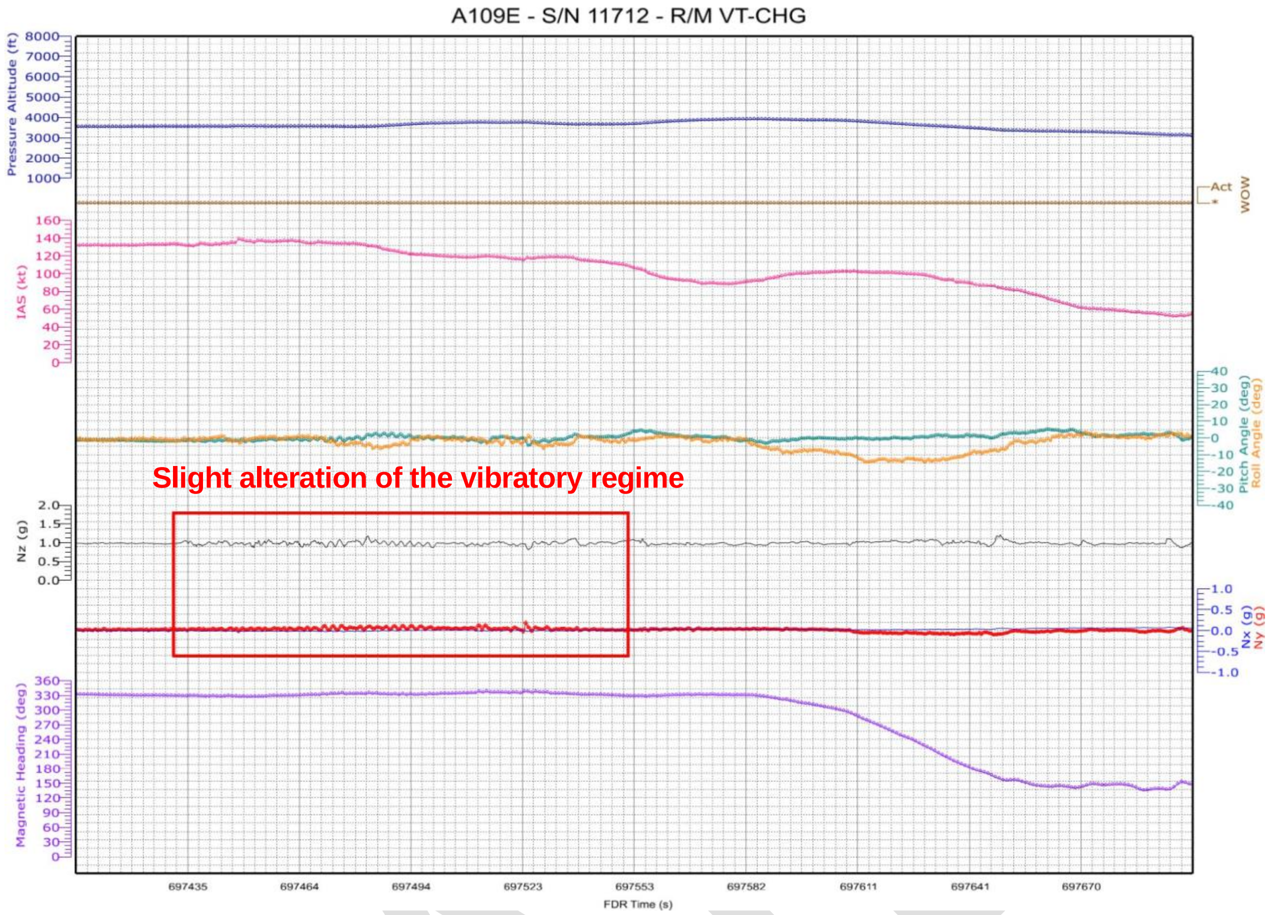


Figure 5. Flight Path Data at the time of TR loss of control

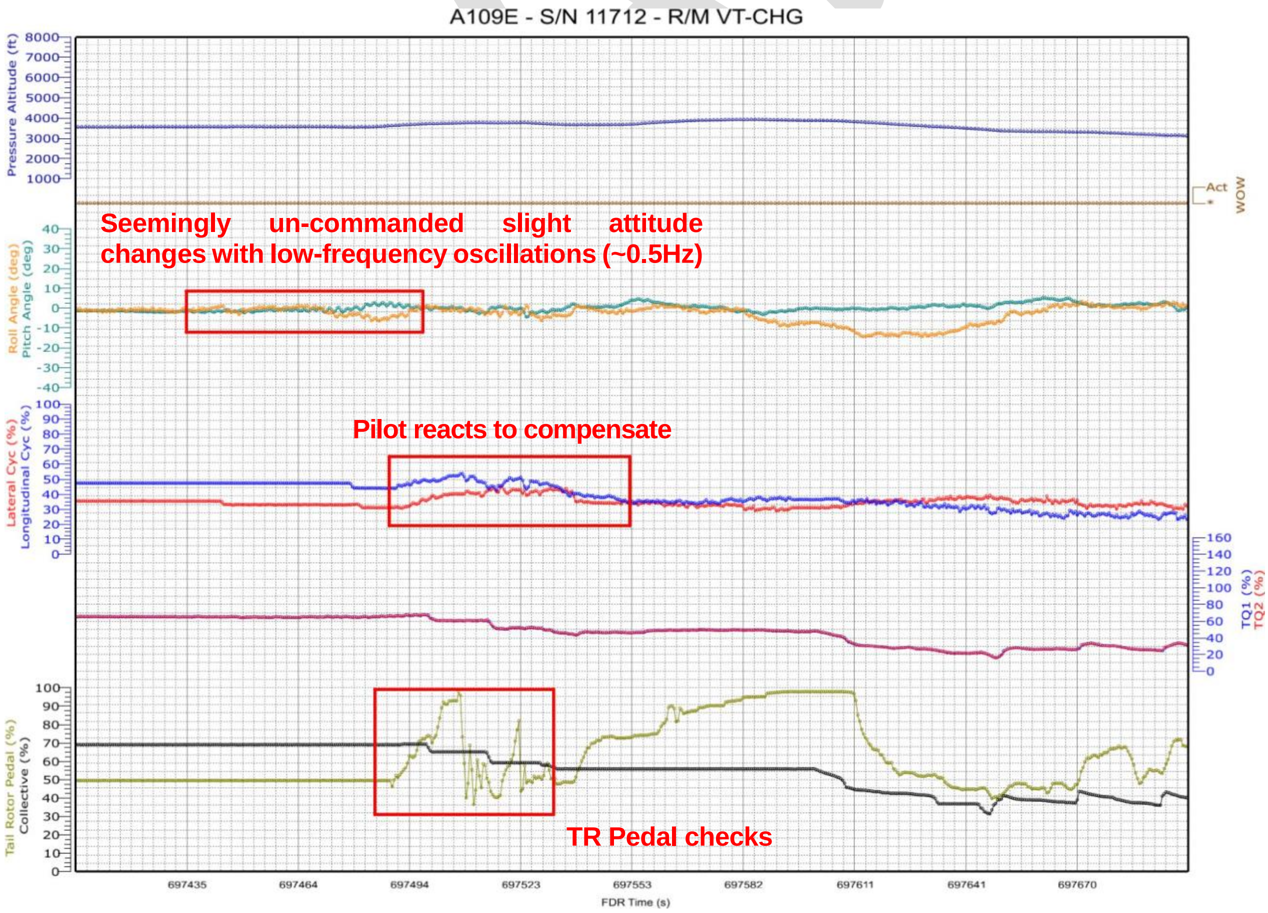


Figure 6. Flight Controls Data at the time of TR loss of control

Figure 7. Power Plant Data at the time of TR loss of control

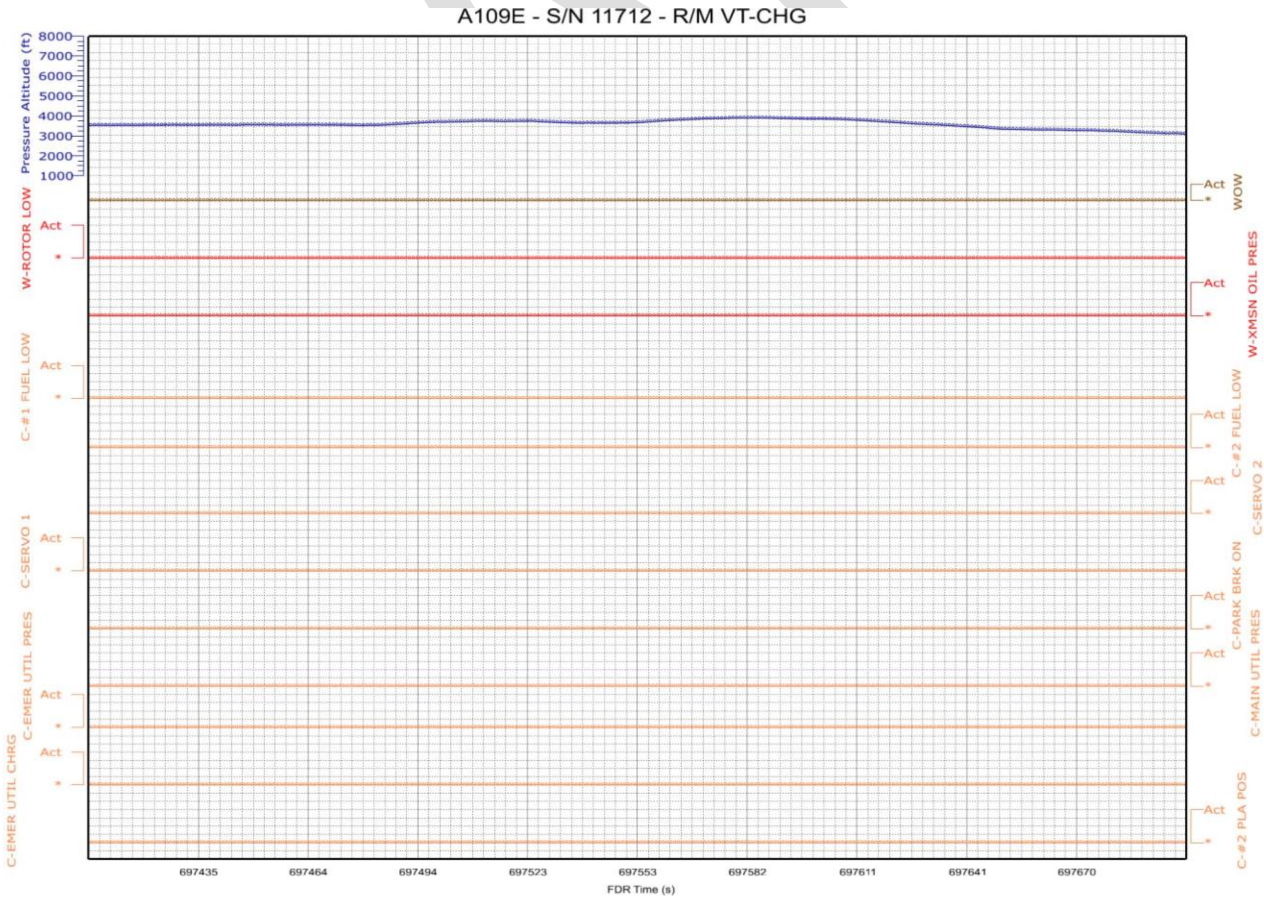


Figure 8. Cautions & Warnings at the time of TR loss of control

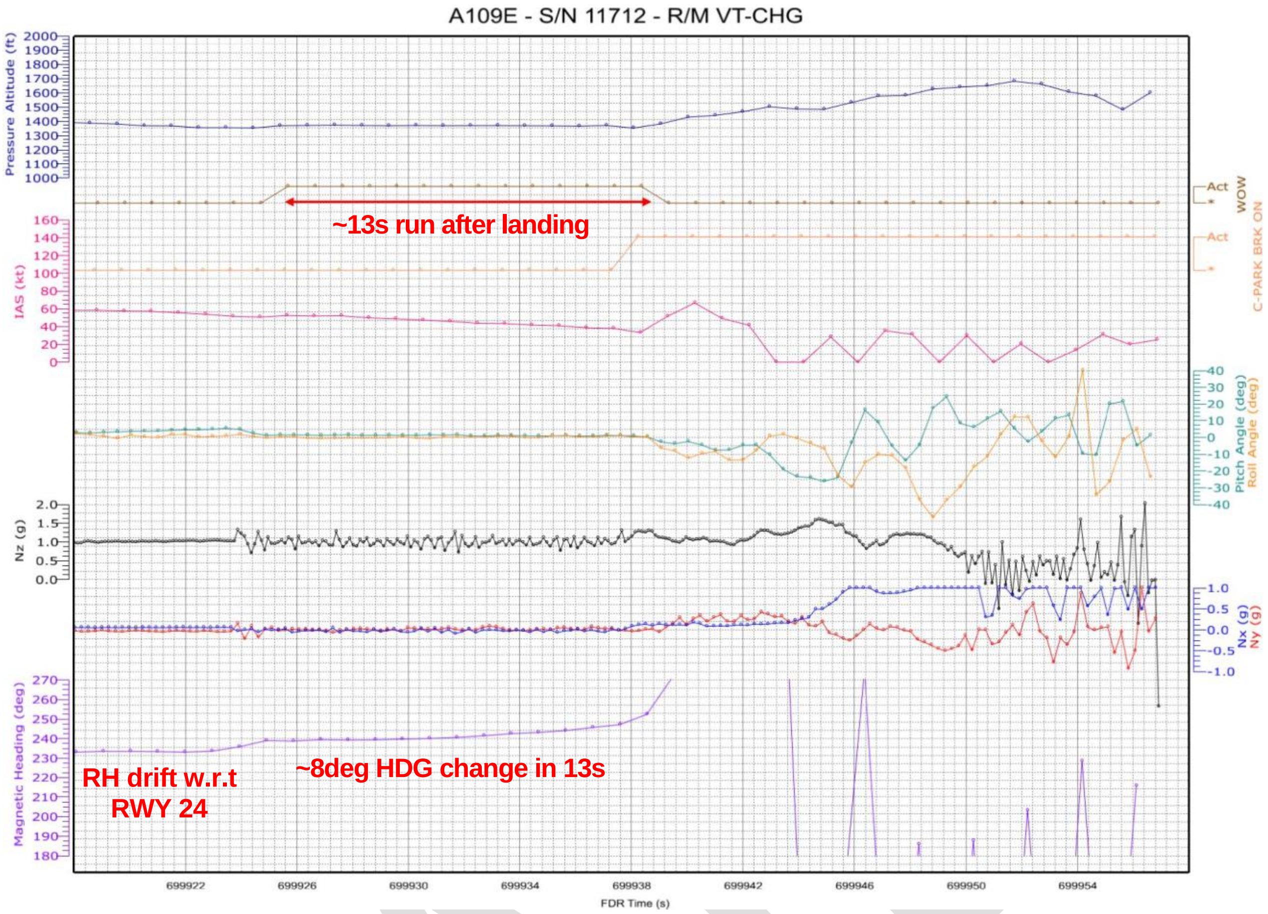


Figure 9. Flight path data for the running landing and accident.

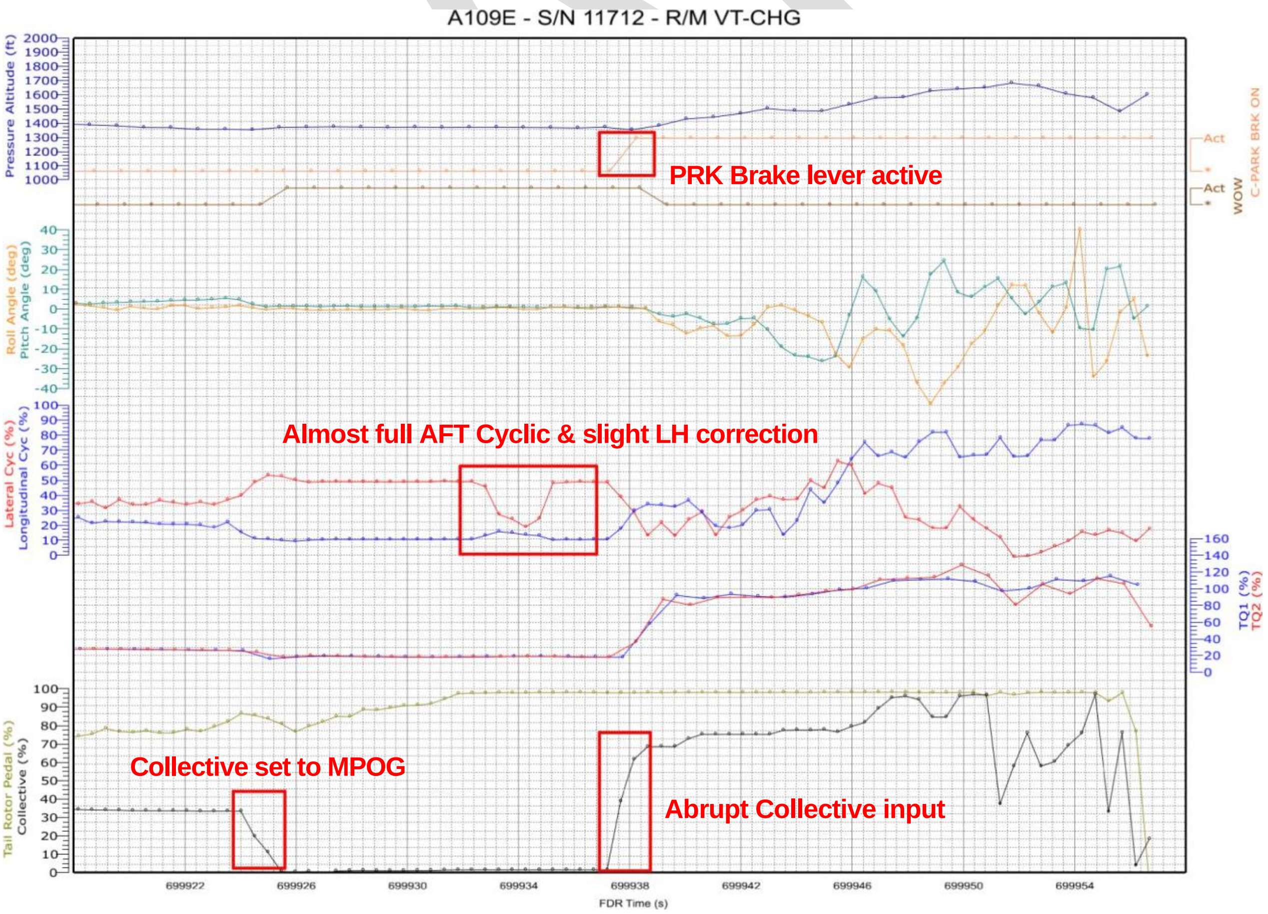


Figure 10. Flight controls data for the running landing and accident.

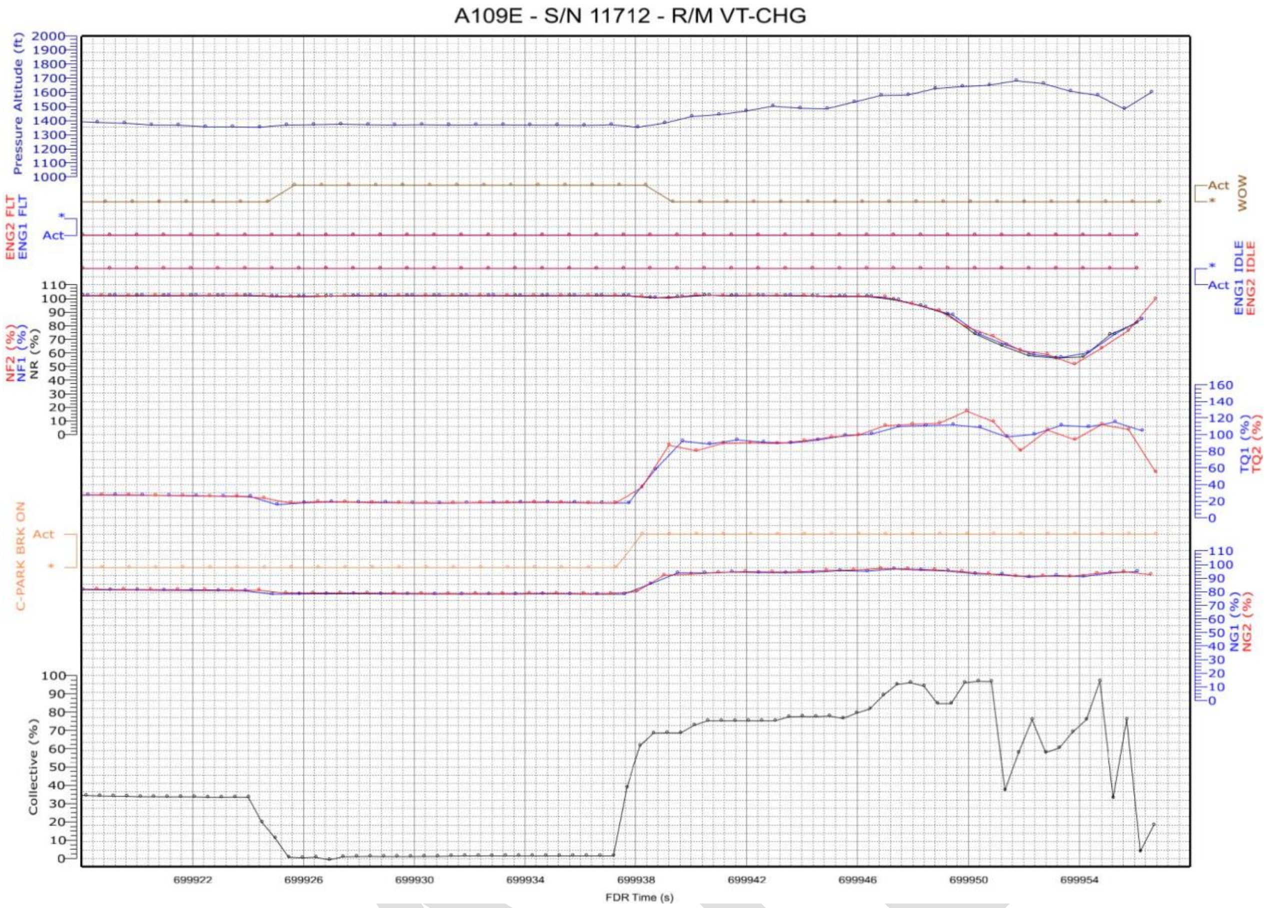


Figure 11. Power Plant data for the running landing and accident.

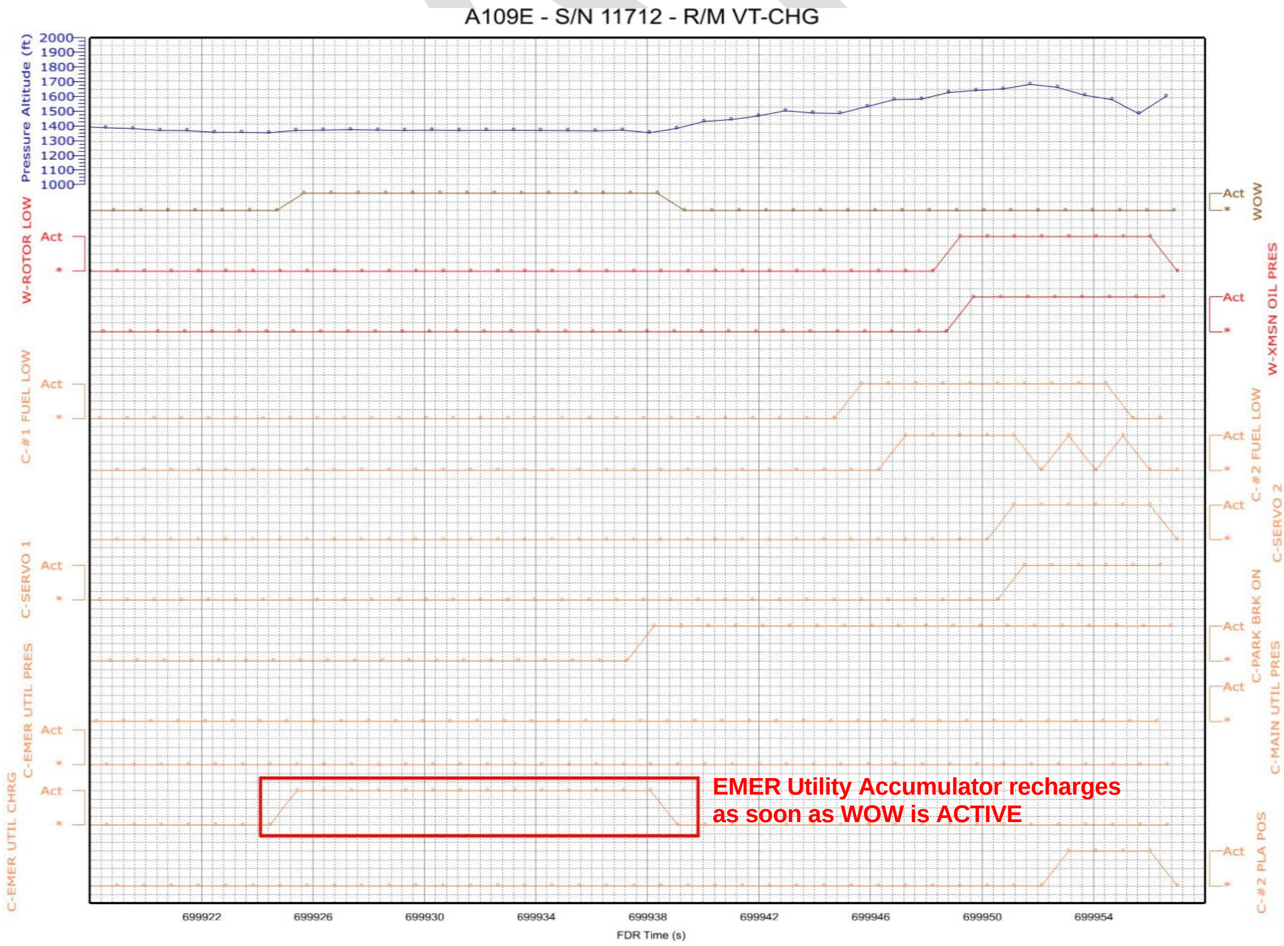


Figure 12. Cautions and Warnings for the running landing and accident.