FINAL INVESTIGATION REPORT ON INCIDENT TO M/s. ALLIANCE AIR ATR 72-600 AIRCRAFT, VT-RKM ON 03.07.2023 IN MUMBAI TMA

GOVERNMENT OF INDIA
O/o, DIRECTOR AIR SAFETY, WESTERN REGION,
NEW INTEGRATED OPERATIONAL OFFICE COMPLEX,
SAHAR ROAD, VILE PARLE (EAST), MUMBAI-400099

FOREWARD

This investigation is performed in accordance with The Aircraft (Investigation of Accidents and Incidents) Rules 2017 of India. The sole objective of this investigation is to prevent aircraft accidents and incidents. It is not the purpose of this investigation 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 accidents or incidents could lead to erroneous interpretations.

CONTENTS

ABBREVIATIONS

A/c	Aircraft
Aircraft	Incident aircraft
AFCS	Automatic Flight Control System
AME	Aircraft Maintenance Engineer
AMM	Aircraft Maintenance Manual
AMP	Aircraft Maintenance Programme
AMSL	Above Mean Seal Level
AP	Auto Pilot
ARC	Airworthiness Review Certificate
ATC	Air Traffic Control
ATPL	Air Transport Pilot's License
GOI	Dabolim (Goa) Airport
BBB	Mumbai VOR Identifier
BOM	Mumbai Airport
CAC	Core Avionics Cabinet
CAMO	Continuing Airworthiness Management Organization
CL	Condition Lever
CPL	Commercial Pilot's License
CSMIA	Chhatrapati Shivaji Maharaj International Airport
CSN	Cycles Since New
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DGCA	Director General of Civil Aviation, India

DME	Distance Measuring Equipment
ECTM	Engine Condition Trend Monitoring
ENG	Engine
FCOM	Flight Crew Operating Manual
FD	Flight Director
FDTL	Flight and Duty Time Limitations
FGCP	Flight Guidance Control Panel
FL	Flight Level
FO	Co-Pilot/ First Officer
FRB	Flight Report Book
FRTO	Flight Radio Telephone Operator
FSD	Flight Safety Department of M/s Alliance Air
GPS	Global Positioning System
IATA	International Air Traffic Association
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
I/O	Input/ Output
IR	Instrument Rating
LH	Left Hand
LLR	ALLIED (R/T Designator of Alliance Air)
MEL	Minimum Equipment List
OEM	Original Equipment Manufacturer

Operator	AOP holder of the incident aircraft
PDR	Pilot Defect Report
PFR	Post Flight Report
PIC	Pilot in Command
PL	Power Lever
PPC	Pilot Proficiency Check
QNH	Pressure setting to indicate altitude above MSL
QRH	Quick Response Handbook
RADAR	Radio Detection and Ranging
RESA	Runway End Safety Area
RH	Right Hand
R/T	Radio Telephony
TCAS	Traffic Collision Avoidance System
TSN	Time Since New
TQ	Torque
UTC	Coordinated Universal Time
VABB	Mumbai Airport
VFR	Visual Flight Rules
VOR	Very high-frequency Omni Range
YD	Yaw Damper

FINAL INVESTIGATION REPORT ON INCIDENT TO M/s. ALLIANCE AIR ATR 72-600 AIRCRAFT, VT-RKM ON 03.07.2023 IN MUMBAI TMA

1.	**Aircraft**	**Type**	ATR 72-600
2.		**Nationality**	Indian
3.		**Registration**	VT-RKM
4.	**Owner**		Dae Leasing (Ireland) 24 Limited, 70 Sir John Rogerson's Quay, Dublin 2, Ireland
5.	**Operator**		Alliance Air Aviation Limited, India
6.	**Pilot In- Command**		ATPL holder
7.	**Co-Pilot**		CPL holder
8.	**Extent of Injuries**		Nil
9.	**Date and Time of Incident**		03/07/2023, 17:21:48 UTC approx.
10.	**Place of Incident**		Mumbai TMA
11.	**Geographical location of site of Occurrence (Lat. Long.)**		19°09'42"N, 73°04'57"E
12.	**Last point of Departure**		Dabolim Airport, Goa
13.	**Intended Place of Landing**		CSMIA, Mumbai
14.	**No. of Personnel On-Board**		73 (68 passengers + 5 crew members)
15.	**Type of Operation**		Scheduled Revenue
16.	**Phase of Operation**		Approach
17.	**Type of Incident**		System/Component Failure - Non-Power plant (SCF-NP)

Timings are expressed in UTC. In order to give better perspective, local timing in IST (UTC +5:30) is also mentioned for the important events.

SYNOPSIS

On 03rd July 2023, M/s Alliance Air was operating their ATR-72 aircraft bearing registration VT-RKM as scheduled flight LLR658 on sector Dabolim, Goa – Mumbai, which was the fourth flight of the day for the aircraft and the operating crew. No snag/defect was reported for any of the previous sectors. Post-completion of pre-flight inspection by the AME and thereafter by the PIC, the aircraft was ready for departure. The aircraft got airborne at 16:17:34 UTC from RWY 26.

After an uneventful take-off, climb, cruise and descend, except for the weather, the aircraft was being radar vectored by the Mumbai Approach (Arrival) Controller for an ILS 27 approach. The aircraft was given vectors from north of BBB due to weather and was given a descent to FL070. At around FL075, the crew started feeling vibrations from the left side of the aircraft and asked for the possibility of giving priority in landing. The priority was not accorded by ATC due to traffic however agreed to accommodate them early. Subsequently to comply with the ATC instructions, while the aircraft was taking a right turn under A/P, the aircraft had banked right beyond the A/P limits to a maximum of 40 deg and excessive vibrations and controllability issues were felt. A/P was disengaged by the PIC and a left control wheel force was applied by both the crew. Further, the power lever of ENG#1 was brought to idle followed by feathering the LH propeller. PAN PAN was declared and priority landing was sought by the crew citing technical issues. ATC approved priority landing and the aircraft was then vectored to capture the localizer. The aircraft was then handed over to the TWR. As the aircraft was on short finals, ENG#1 fire warning was triggered which was acknowledged by the crew and continued to land. The aircraft landed safely at 17:34:16 UTC, and the ENG# 1 fire warning went OFF. Subsequently, ENG# 1 was shut down by the crew and the aircraft taxied with a single engine (ENG# 2) to the bay. No fire or smoke was observed by the ARFF personnel after landing.

The incident was investigated by Investigator In-Charge and the Member, appointed by DGCA, India vide order no. DGCA-15018(02)/11/2023-DAS dated 14/07/2023 in the exercise of power under Rule 13(1) of the aircraft (Investigation of accidents and incidents) Rules 2017. The conclusion of the investigation was derived based on the inputs of OEMs, i.e. M/s ATR and M/s Thales. The most probable cause of the incident was identified to be the delaminated de-icer boot (zone 616), however, due to lack of detailed information such as dimensions and extent of the patch on the delaminated area, the cause could not be conclusively determined.

1 FACTUAL INFORMATION

1.1 History of the Flight

1.1.1 Prior to Departure

On 03.07.2023, an ATR-72 aircraft bearing registration VT-RKM, belonging to M/s Alliance Air, was scheduled to operate its flight on sectors Mumbai – Diu – Mumbai – Goa – Mumbai. All four sectors were being operated by the same set of crew.

The aircraft had operated first three sectors uneventfully and was prepared to operate on sector Goa – Mumbai as flight LLR658. After the walk around inspection by the AME at Goa, the aircraft was handed over to the flight crew. A total of 68 passengers were boarded along with one type rated AME and two cabin crew.

1.1.2 Departure and Climb

Although the STD was 15:55 UTC, the aircraft had started its pushback from the stand at approx. 16:08 UTC. The PIC was the PF while FO was the PM. The aircraft was given a taxi clearance followed by a departure clearance and line-up clearance by the ATC.

At 16:16 UTC, the aircraft was cleared for take-off and the aircraft was airborne at 16:17 UTC from RWY 26. At 16:17 UTC, while the aircraft was passing 90 ft RA, YD was engaged and subsequently the controls were taken over by the FO. During the initial climb, the crew encountered the weather. Further during a climb, the PIC observed the fluttering of the tape which was applied at the LH cockpit fixed side window which ceased subsequently. The tape was applied as part of rectification action on 26.06.2023 and was to be removed after 10 days as per DMR entry. Later, as PIC checked for the condition of wings and engine from cockpit and he found the condition to be normal. No deviations in the engine parameters were observed by the crew.

The aircraft thereafter came in contact with Mopa Control which gave them a climb up to FL160 with a direct to waypoint OKILA, and while passing 5922 ft, A/P was engaged.

1.1.3 Cruise and Descend

While climbing passing FL153, the crew came in contact with Mumbai Area Control Centre South sector (ACC-S) and was cleared for MOLGA2A arrival for RWY 27 and a direct to MOLGA. At approx. 16:45 UTC the aircraft had reached the cruising altitude of FL160. The flight crew, after coming in contact with Mumbai Lower Area Control (LAC), requested for any direct route to which the ATC cleared them for a direct to DUGED (Terminal Area Waypoint of MOLGO2A). The crew were encountering

weather enroute. The crew had taken the aerodrome weather information from the ATIS. At 17:08 UTC, ATC had cleared LLR658 to descend to FL120. After the briefing for approach and landing, ATC cleared the aircraft to descend to FL100 and then to FL090. LLR 658 was then changed over to Mumbai Approach (Arrival) which cleared them to descend to FL080. Further heading and descend clearances were given by the ATC for an approach from the north.

1.1.4 Controllability and Vibration issues during approach

When the aircraft was proceeding to north of Mumbai for being vectored from the north, at 17:17 UTC, ATC had instructed the aircraft to descend to FL070. Subsequently, while descending passing FL075 the crew asked to ATC for a possibility of giving priority landing as they felt vibrations from the left side of the aircraft. The priority was not accorded by ATC due to traffic however agreed to accommodate them early and was given further descend to FL060 and thereafter, FL055. Later, the PIC reduced the power of both the engines to idle.

As the aircraft was descending passing FL060 and was at approx. R-070/13 NM BBB, the ATC, at 17:21:36 UTC, instructed LLR658 to turn right heading 160. The aircraft started banking to the right for the turn under the A/P and continued banking beyond the A/P limit of 27 deg. Excessive vibrations were also felt by the crew. On realizing the exceedance, PIC disengaged the A/P and taken over controls manually. The PIC informed the FO to request for a priority landing with the ATC. The FO informed the ATC about the same and priority landing was acknowledged by the ATC followed by instructing aircraft to turn right heading 180. Thereafter, the PIC increased the power of ENG#2 while the power lever of ENG#1 was kept at idle. The aircraft was instructed to descend to 3800 ft on QNH 1004 while the crew were troubleshooting the excessive vibrations. Subsequently, the condition lever of Propeller#1 was brought to the feathered gate. Meanwhile, the aircraft descended below MSA of 3800 ft. At 17:24 UTC, PAN PAN was declared by the crew. ATC acknowledged the same and asked to the crew for their intentions. Crew sought priority landing citing technical reasons. ATC gave a heading of 210 for interception of localizer.

Thereafter at 17:25 UTC when passing 3491 ft on standard pressure setting, the QNH was set to 1004 by the PIC while the control wheel was held by the FO for time being. The ATC informed the flight crew to maintain 3000 ft while they were descending passing 3389 ft. The approach checklist was completed and cabin crew was briefed about the one-engine landing by the PIC. After ATC gave heading 220 and enquired for any assistance, to which FO replied no assistance required. Thereafter, PIC informed the ATC that they are landing with single-engine. ATC instructed to descend to 2600 ft and cleared them for ILS 27. The aircraft was changed to tower frequency when 8NM short of runway and was instructed to continue approach.

1.1.5 Engine Fire warning on short finals

The landing gears were extended and flaps set to 30 deg. At 17:31 UTC, the aircraft was cleared to land at RWY 27. The crew carried out the before landing checklist and thereafter, as instructed by PIC, FO disconnected the YD. While the aircraft was at 429 ft AGL, ENG#1 fire warning was triggered for three seconds. The same was reported to the ATC and the ATC declared full emergency. The aircraft landed safely at time 17:34 UTC on single engine and vacated via RET N8. The fire warning was disappeared from the EWD. Thereafter, further taxi instructions was issued by the ground. The fire manager informed ATC that the aircraft appears to be normal. The crew also informed the ATC that there is no engine fire warning currently and reported all operations normal. After confirmation from fire manager about absence of fire and smoke during visual observation, aircraft was instructed to follow follow-me jeep to dock at stand C27.

1.2 Injuries to Persons

Injuries	**Crew**	**Passengers**	**Others**
Fatal	Nil	Nil	Nil
Serious	Nil	Nil	Nil
Minor	Nil	Nil	Nil
None	05	68	---

1.3 Damage to Aircraft

There was no damage to the aircraft.

1.4 Other Damage

Nil

1.5 Personnel Information

	Captain	First officer
Age	47 years	36 years
License	ATPL	CPL
Date of Issue	15.11.2014	07.01.2011
Valid up to	14.11.2026	24.03.2026
Category	Aeroplane	Aeroplane
Date of Class I Medical Exam	06.12.2022	17.08.2022
Class I Medical Valid up to	21.12.2023	19.08.2023
Date of Issue of FRTO Licence	25.09.2007	07.01.2011
FRTO Licence Valid up to	20.06.2036	28.01.2026
IR rating	ATR 42/72-600	ATR 42/72-600
Total Flying Experience	7366	1850 Approx.

Total Flying Experience on Type	7100	1630 Approx.
Total Flying Experience in last 1 year	710:30	475:52
Total Flying Experience in last 6 months	288:47	208:35
Total Flying Experience in last 30 days	45:30	52:22
Total Flying Experience in last 7 days	15:05	28:39
Total Flying Experience in last 24 hours	5:22	6:13
Duty Time last 24 hours	8:16	9:07
Rest before the incident flight	24:20:00	12:53
Ratings	C-152, P68, ATR42/72-600	C-152, P68, ATR 42/72-600

1.6 Aircraft Information

1.6.1 General

ATR 72-212A '600 Version' is a glass cockpit equipped aircraft installed with Pratt and Whitney PW-127 turboprop engine. The Aircraft VT-RKM (MSN: 1463) was manufactured in year 2019. The aircraft was then registered with the DGCA.

The Certificate of Airworthiness Number 7141 under 'Normal' category with subdivision "Passenger/Mail/Goods" was issued by DGCA on 28.02.2019. The specified minimum operating crew is "two" and the maximum all up weight is 23,000Kgs. The ARC physical survey and inspection was last carried out by the Airworthiness Review Staff of M/s Alliance Air CAMO and the ARC was issued on 22.02.2023 which was valid till 27.02.2024.

The CAMO records indicate that the aircraft and its engines were being maintained as per the maintenance program approved by DGCA, consisting of Calendar Period/ Flying Hours based maintenance. All the concerned Airworthiness Directive, mandatory Service Bulletins, DGCA Mandatory Modifications on this aircraft, its engines and propellers were complied with as of the date of the incident.

The last major inspection (9A check) was completed on 25.04.2023 when the aircraft accumulated approx. 5964:53 FH and 5629 FC. The last scheduled inspection carried out on the aircraft prior the incident was 400 FH check on 04.06.2023.

On the day of occurrence, MEL 26-12-01 Cat 'C' for ENG#2 Loop B was active. This was invoked on 01.07.2023 as the fire test was inoperative during cockpit preparation. The MEL was valid till 11.07.2023.

Further, aluminum tape was applied on 26.06.2023 at the LH forward fixed window in the cockpit as part of the rectification to the reported defect of water seepage. A DMR entry in this regard was also made in the FRB for information to the pilots/engineers

and the tape was to be removed after 10 days, i.e. on 05.07.2023. The status of the tape was to be checked by the certifying staff before each flight. Transit inspection was carried out by the certifying staff at Goa and no abnormalities were observed. Other than the above mentioned deferment action, there was no technical issue existed in the aircraft.

1.6.2 Automatic Flight Control System (AFCS)

The ATR 72-212A aircraft is equipped with the AFCS which fulfills the three following functions:

- Flight director (FD):

When the FD is active the crew is provided with tendency data by means of the FD crossed bars on the PFDs. The crew guides the aircraft along a flight path by centering the bars and keeping them centered. The FD bar position on the PFDs varies according to the difference between the parameter advisory value which is to be acquired or held and its present value.

- Autopilot (AP):

Effective guidance is ensured by the AP. It is possible to keep FD data in upper modes (AP/ FD function) but not in basic mode (AP function alone).

The AP commands are applied to the control surfaces by three actuators: the pitch, roll and yaw actuators. Moreover elevator compensation command sent to the normal pitch trim actuator (autotrim function). The controls (control wheel, rudder pedals) are driven by the actuators. Autopilot authority domain is limited to 27 ° in high bank and 15 ° in low bank (when IAS < final approach speed).

- Yaw damper/ turn coordination or YD :

In addition to yaw damper in manual flight, this function ensures turn coordination. Commands are sent to the AP yaw actuator. As the rudder pedals are driven by the actuator, the crew does not have to operate them.

Main components of the AFCS are:

- Two Core Avionics Cabinet (CAC 1 which controls the autopilot functions, and CAC 2 which monitors the autopilots functions)
- Three control panel: one Flight Guidance and Control Panel (FGCP) and two Index
- Control Panel (ICP)
- Two Flight Mode Annunciator (FMA), one on each PFD upper part
- Three identical servo actuators on the three axes (pitch, roll, and yaw)
- One Power Trim Box (to interface with the pitch trim actuator).

FMA, FGCP, ICP, computers, and pitch trim box are located at the Cockpit and electronic rack).

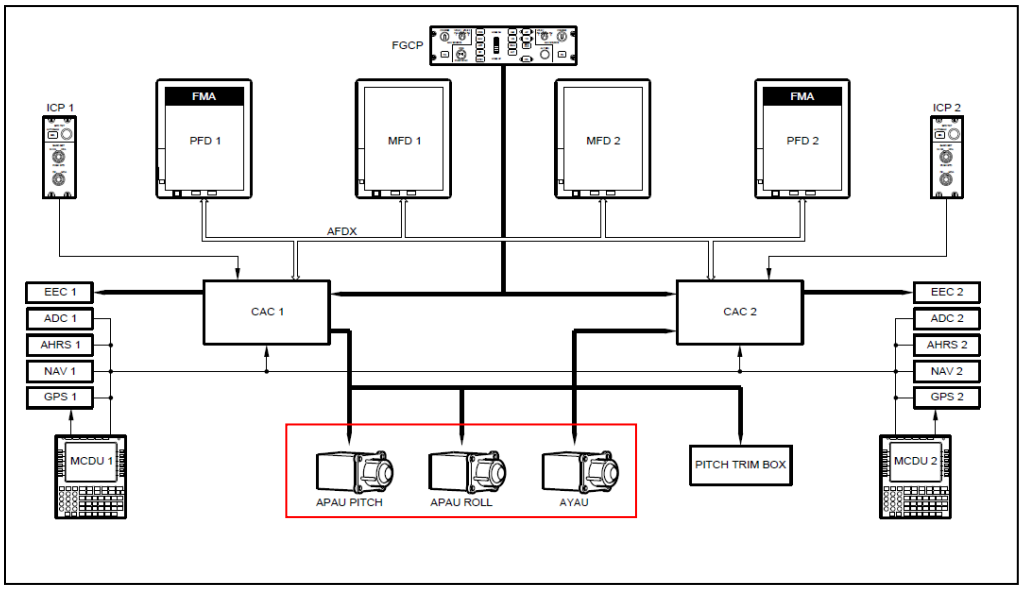


Fig. 1: AFCS System Schematic (Source: FCOM)

1.6.2.1 A/P Roll Control and its Mechanical Linkage

AP orders are followed up by three electrical actuators which drive pitch, roll and yaw flight controls (Refer Fig. 1). The actuators are installed in parallel, i.e., actuator movement is transmitted to the control wheels and to the control surfaces and cable drum connection and the cable drum itself are integrated in the manual flight controls. For the three axes, connection is performed at the junction of the cable section with the flight control rods section.

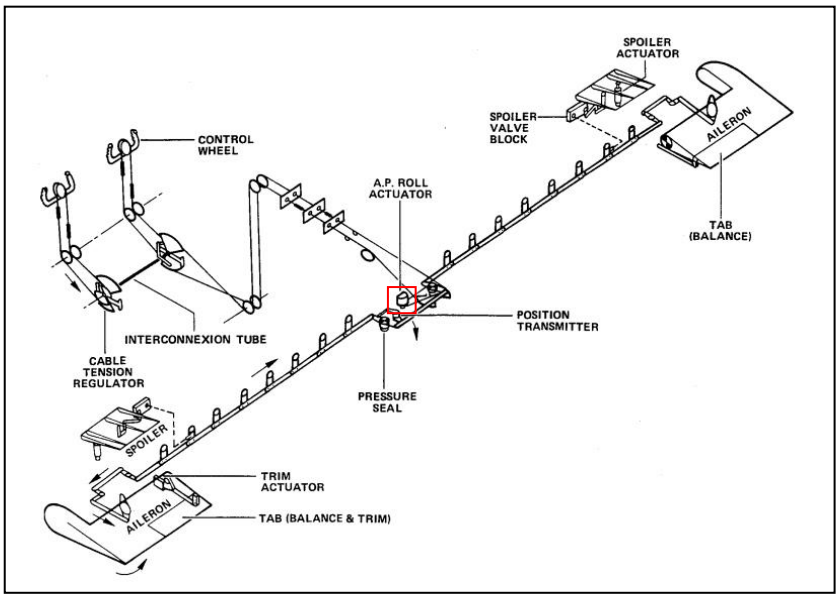


Fig.2: AP/Mechanical Linkage Interface (Roll) (Source: AMM)

The AP roll actuator is secured on a mount attached on the aft center section of the wing center box. The actuator cable drum is linked by two cables to a quadrant connected to the bulkhead through fitting linking the manual flight control (in cabin) and the rod actuating bellcrank.

The actuator is divided in two different parts, the capstan and the servomotor. They are independent, which allows changing the servomotor without removing the capstan integrated in the flight controls.

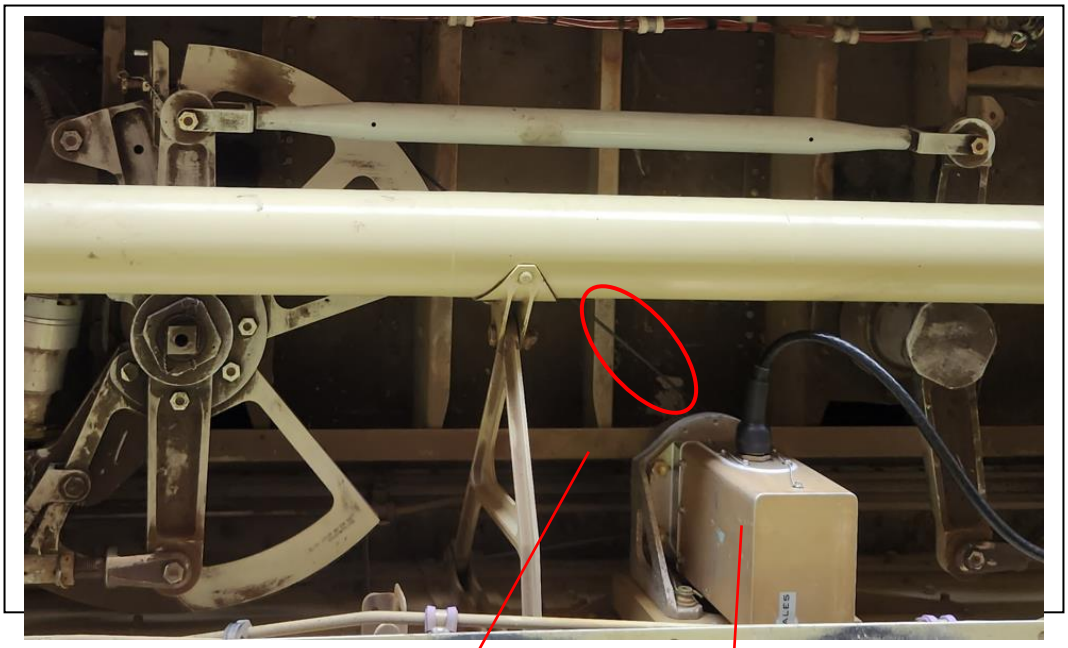


Fig.3: A/P Roll actuator cable connection to the roll quadrant *(picture taken after the rectification action)*

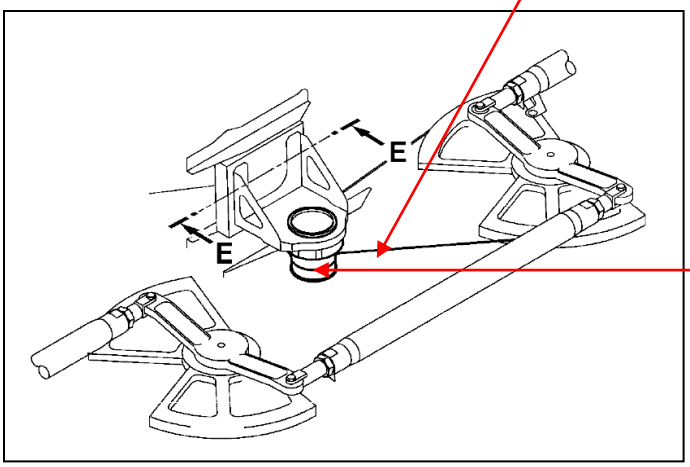


Fig.4: A/P Roll actuator cable

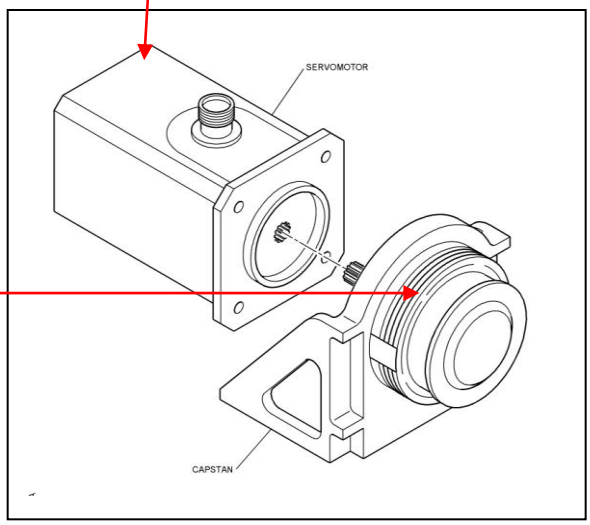


Fig.5: Servomotor and the Capstan

1.6.3 Maintenance Troubleshooting

1.6.3.1 Initial Observations

A defect entry for the incident flight was made by the PIC as 'Major vibration felt and bank angle went steep around 40deg with A/P ON and some loss of control felt during STAR and Eng# 1 fire alarm on short finals'.

During in-situ inspection of the aircraft after landing, both the inboard and outboard cowlings of ENG#1 were opened for visual inspection. No signs of fire such as carbon deposit, coking, burnt smell, etc was observed during the inspection. The segments of both loops were visually checked, to the possible extent, to detect any cracks/breakage/nicks and were found satisfactory. The security of the installation of the rail mounts for the loops was also checked, to the possible extent, and found satisfactory.

The 'DISCH' legend on SQUIB pushbutton for the release of fire extinguishing agents were found to be OFF indicating the fire bottle was not discharged. Flight control-related faults were neither recorded in the system-generated incident flight report nor in the fault memory. The system-generated incident flight report of the incident leg is reproduced below.

Time (UTC)	Master Caution /Master Warning	Fault Message
17:23:14	MC	APM FAULT
		ACW GENERATOR 1 FAULT
		ENG 2 LOOP B FLT
17:33:06	MW	ENGINE 1 FIRE OR DAMAGE
	MC	ACW GENERATOR 1 FAULT
		ENG 2 LOOP B FLT

The fault messages pertaining to APM and ACW GEN#1 were recorded which were generated when the aircraft power levers were pulled to IDLE whereas ENG# 2 LOOP B FAULT was recorded due to an existing MEL.

1.6.3.2 Detailed Troubleshooting

The aircraft was brought to the hanger of maintenance agency M/s AIESL for detailed troubleshooting and an engineering order was issued in this regard. Initially, a preliminary visual inspection of the ENG#1 was carried out along with the engine shock mount inspection which were found normal. Propeller rotation check, power lever and condition lever movement were also carried out and was found to be normal. M/s ATR was later approached by the operator for further rectification and the ATR had recommended necessary inspections to identify the cause for in-flight vibrations and flight control issues. This included inspections into aircraft structure, flight control (all axis along with flaps and spoilers), landing gears, powerplant and air conditioning.

The vibration reporting sheet submitted by the PIC to the maintenance crew indicated that the flight crew had felt continuous vibrations during descend from FL070 which were mostly of lateral in direction. The vibrations were felt in the control wheel on both

PIC side and FO side. No vibrations were felt in the rudder pedals. The flight crew had also indicated that the vibrations were accompanied by abnormal noise probably originating from the flight deck/LH wing. The reduction of speed and feathering of propeller#1 resulted in reduced vibration.

In accordance with the recommended inspections by the ATR, the CAMO issued a work order. Initially, the operational test of aileron control and tab, rudder control and spring tab, elevator control and tab, and wing flaps were carried out wherein all the tests were satisfactory. Further, the operational test of the AFCS test was carried out on 08.07.2023, through MCDU system test, for the first time since the incident and the same was found to be satisfactory. This test ensures the computers and components related to the AFCS are free of defects/faults.

The certifying staff continued to carry out the necessary inspections as recommended in the work order covering inspections relevant to flight control (Roll) such as the inspection of aileron structure, component and cable inspection, the tension check of roll control cables, visual check of cable tension regulators and the tension check of all regulated and non-regulated cable loops. Further, inspections on the colour of aileron trim actuator desiccant cartridge, aileron trim and tab control linkage, aileron mechanism control in cabin, aileron mechanical control in wings, spring tab leaf spring, wing rear-spar aileron hinge-fittings and aileron tab hinge fitting were carried out. All the inspections were found satisfactory.

1.6.3.3 Tension of A/P Roll Actuator Cable

The operational test of the AFCS was again carried out on 11.07.2023 which was satisfactory. Thereafter, the operational test of the A/P roll actuator was carried out which had failed. Hence, the certifying staff recorded to carry out further investigation.

The A/P roll actuator cable tension was checked, however, the tension was found to be approx. 20 lbf which is below the limits mentioned in the maintenance data. As per the maintenance data, the cable tension should be 35.97 ± 4.50 lbf (160 ± 20 N). The zero electrical mark on the actuator was slightly misaligned, however, was within the AMM limits.

The DVI of the roll actuator and the capstan were checked which were satisfactory. The in-situ condition of the A/P roll cable was satisfactory and no damage was observed. The attachment of the cable to the quadrant was fine and the lock nuts were properly wire locked.

The same roll cable was used for adjusting the tension to the limits specified in the maintenance data as there was no abnormality w.r.t. the roll cable. A duplicate inspection of roll control was also carried out by another certifying staff, which was satisfactory. Subsequently, the servo motor (S/N: 2016) of the A/P roll actuator was replaced with a repaired one (S/N: 1302).

Subsequent to the replacement of A/P roll actuator servo motor, the operational test of A/P roll actuator was carried out however the test failed again and AP/YD INVALID

message appeared on PFD. Thereafter the AFCS operational test was also carried out and it also failed. Troubleshooting for the same revealed that the 5024VC connector pin 3 & 4 used for A/P engagement/ disengagement logic were adrift, the same were reinserted properly and subsequently AP/YD INVALID message disappeared. A/P roll actuator operational test and AFCS test were passed subsequently. However, Input/ Output module card of CAC1 was replaced as precautionary measure.

1.6.3.4 Delamination of RH wing de-icer boot patch

During the troubleshooting, the maintenance staff had identified the delamination of the de-icer boot patch in Zone 616 of the RH wing. Hence, the de-icer boot of Zone 616 was replaced with a serviceable one. Operational test of aerofoil de-icing system was carried out which was satisfactory. The RH wing leading edge assembly was sent to the DGCA approved 145 facility for de-icer boot replacement without any clearance from DGCA or the FSD of M/s Alliance Air despite being an incident-involved item.

As the maintenance crew had not taken the measurements of the delaminated area of the patch, the same could not be passed on to the ATR for their analysis. Further, the ATR could not ascertain the damage to the boots from the photographs which were captured after the incident and provided by M/s Alliance Air. Additionally, schematic and/or pictures indicating the exact locations of damage on the boots on the wing leading edge could not be provided by M/s Alliance Air to ATR.

1.6.4 History of maintenance on Flight Control (Roll)

A/P roll actuator is an on-condition item. After the induction into the fleet of M/s Alliance Air, the aircraft had undergone the scheduled maintenance as per the AMP. None of the schedules specifies any of the inspections at the aft center section of the wing box where the A/P roll actuator, its cable and the roll control quadrant are located, for the hours accumulated by the aircraft.

The records indicate that the servomotor of the A/P Roll actuator (P/N: C18427AA, S/N: 247) was replaced on 04.06.2020 with a new servo motor (S/N: 2016) by the certifying staff for the PDR entry “A/P disconnect in flight 1. After Take-off 2. In turns and during turbulence”. Installation of the roll actuator includes the procedure for the adjustment of A/P roll actuator cable tension. Further to this replacement, no work was done on any of the flight control (roll) components in the aft center section of the wing box area. Further, no abnormal vibrations or controllability issues were reported/ recorded prior to the incident flight.

1.6.5 Engine#1 Fire Warning

During the troubleshooting, no signs of fire/smoke was observed at the ENG#1. As stated in Para 1.6.3.1, no abnormalities were observed w.r.t the fire detection loops. The maintenance records pertaining to the engine fire detection loops were satisfactory. Both the loops of ENG#1 were working normally at the time of occurrence. No replacement was done in this regard.

A similar event was recorded on 12.06.2023 on the same aircraft during its pushback for operating flight LLR661. ‘NAC OVHT’ message appeared during the pushback

followed by ENG#2 fire warning. No traces of fire/smoke was detected. The PIB concluded the same as false warning probably due to the prevailing tail wind.

1.6.6 FCOM Actions during Vibration

The FCOM does not categorically mention the actions to be taken by the flight crew when the vibrations are experienced. The abnormal conditions which could result in vibrations stated in the FCOM includes the mechanical damage to propeller or engine in flight, engine flame out, aircraft experiencing stall and the conditions of icing.

The FCOM recommends the crew to carryout following procedures for sudden and high vibrations:

▶ ICING CONDITIONS..... ..... CHECK
Unbalanced blade icing may also generate propeller vibrations.
In this case Refer to AFM - Procedure for Icing Conditions, or Refer to AFM - QRH SEVERE ICING procedure.

▶ ENG PARAMETERS..... ..... CHECK
Check for any fluctuations of power plant parameters that may indicate the affected engine, mainly TQ and NP. Check also for transient or steady alerts (PEC, ACW faults or any other alerts) that may be associated with power plant vibrations and indicate the affected engine.
If affected engine cannot be identified via engine parameters, flight crew should move one PL at a time: it may help to determine the affected side, as the vibrations level and frequency may change with PL position.

■ IF AFFECTED ENGINE IS IDENTIFIED
▶ PL (affected eng)..... ..... FI
▶ CL (affected eng)..... FTR THEN FUEL S.O. LAND ASAP
▶ SINGLE ENG OPERATION procedure..... ..... APPLY

■ IF AFFECTED ENGINE CANNOT BE IDENTIFIED
▶ PL 2..... ..... FI
▶ CL 2..... FTR
■ IF VIBRATIONS SIGNIFICANTLY CHANGE
Engine 2 failure is suspected and should be shut down.
▶ CL 2.....FUEL S.O. LAND ASAP
▶ SINGLE ENG OPERATION procedure..... ..... APPLY
■ IF VIBRATIONS PERSIST
Restore engine 2 and same check repeated on engine 1.

▶ CL 2..... ..... AUTO
▶ PL 2..... ..... AS RQRD
▶ PL 1..... FI
▶ CL 1..... FTR

■ IF VIBRATIONS SIGNIFICANTLY CHANGE

Engine 1 failure is suspected and should be shut down.

▶ CL 1.....FUEL S.O. LAND ASAP

▶ SINGLE ENG OPERATION procedure.....APPLY

There were no snags or defects related to the de-icing system during the flight. Icing conditions were not identified and reported by the crew during the abnormal behaviour of the aircraft. The available evidence does not indicate the possibility of engine flame out or stall or presence of icing condition or any mechanical damage to the engine or propeller.

1.7 Meteorological Information

The crew had been encountering weather since their initial climb. The convective clouds, were prevalent over Mumbai Airspace as observed from the DWR and satellite image products obtained from the IMD. DWR image product is placed in Annexure to this report.

The local forecast for 100 NM around Mumbai which is valid till 2200 UTC indicates that the freezing level would probably be 17224 ft (5250m). Severe turbulence and heavy rain shower was also predicted.

The following was the METAR issued from 1700 UTC to 1730 UTC on 03.07.2023:

VABB 031730Z 00000KT 2500 DZ FEW012 SCT018 FEW030CB BKN090 29/27 Q1004 TEMPO 1500 SHRA=
VABB 031700Z 25007KT 2100 -DZ SCT012 SCT020 FEW030CB BKN090 29/27 Q1004 NOSIG=

The weather conveyed during landing clearance was 230/03KTS.

1.8 Aids to Navigation

All Navigation aids at Mumbai Airport were working normal.

1.9 Communication

There was always a two-way communication between the ATC and the aircraft.

1.10 Aerodrome Information

Chhatrapati Shivaji Maharaj International Airport is an international airport located in Mumbai. The runway available is an instrument runway of orientation RWY 09/27 and RWY14/32. ILS is installed at all the runways except for RWY 32. During the incident, RWY 27 was in use and its ILS was serviceable. ARFF category 10 was maintained during arrival of the incident flight.

1.11 Flight Recorders

The aircraft is equipped with a SSFDR (P/N: 2100-4245-00) which can record the flight data up to 25 hours and SSCVR (P/N: 2100-1225-22) which can record the cockpit sounds for 2 hrs. The salient observations from the flight recorders are mentioned below.

1.11.1 DFDR

Since time 17:15:55 UTC, the aircraft was at FL080 at a position R-140/23NM BBB, on a heading 329 deg with a speed maintained around 182 kt IAS. The A/P and Y/D were engaged. Thereafter, at 17:17:45 UTC, the selected altitude was set to 6992 ft followed by setting the selected heading to 360 deg. After maintaining the same heading, with a speed of around 163 knots, and when the aircraft was at approx. R-086/12 NM BBB, at 17:20:50 UTC, the selected altitude was set to 6000 ft. At this moment, the torque (TQ) generated by ENG#1 and ENG#2 was 54.88% and 53.81% respectively. Within 09 seconds, as the aircraft initiated its descent, the TQ was reduced as the power lever angle was pulled back to flight idle.

At 17:21:21, the selected altitude was set to 5504 ft. At 17:21:40 UTC, as the selected heading is being set to 160 deg, the aircraft started its roll to capture the heading. The control wheels were also moving to the right **(1).** The aircraft was at 5970ft pr. altitude and TAT was recorded as 23.5 degC.

Ailerons were deflected and maintained in a right turn order and the roll angle increased, in accordance with the heading change. As per the ATR, the LH aileron was observed to be more noisy than the RH aileron.

While the aircraft was making a right turn and right bank, when the heading was approx. 8 deg, the roll reached to a value of 27.7 deg **(2)**. However, at this time, the control wheel position was turning to the left from its maximum attained angle of 35deg on the right **(3)**. The LH ailerons were deflected upwards while the RH ailerons were deflected downwards, for banking to the left, corresponding with the control wheel position. Both power levers (P/L) were advanced by 10 deg.

As the control wheel position continued to turn to left and crossed its center position, reaching 11 deg to left, and when the LH ailerons were deflected upwards, the aircraft was banking right reaching approx. 32 deg. As the roll angle reached 39.31 deg, A/P was disengaged at 17:21:57 UTC **(4)**. The roll angle reached approx. 41 deg to the right in a second. P/L#1 was pulled back to flight idle resulting in TQ#2 being ~13% while TQ#1 was ~1%.

After disengaging the A/P, the roll effort input by the PIC on the control wheel parameters showed values of 854N & 1013N. The control wheel position at this moment was approx. 53 deg to the left. The aircraft started rolling towards the left from its maximum attained bank angle of 41 deg to right. By this time, the aircraft had descended up to FL55. The bank angle was brought back to approx. 4.84 deg to right at time 17:22:04 UTC. Power was being adjusted as required.

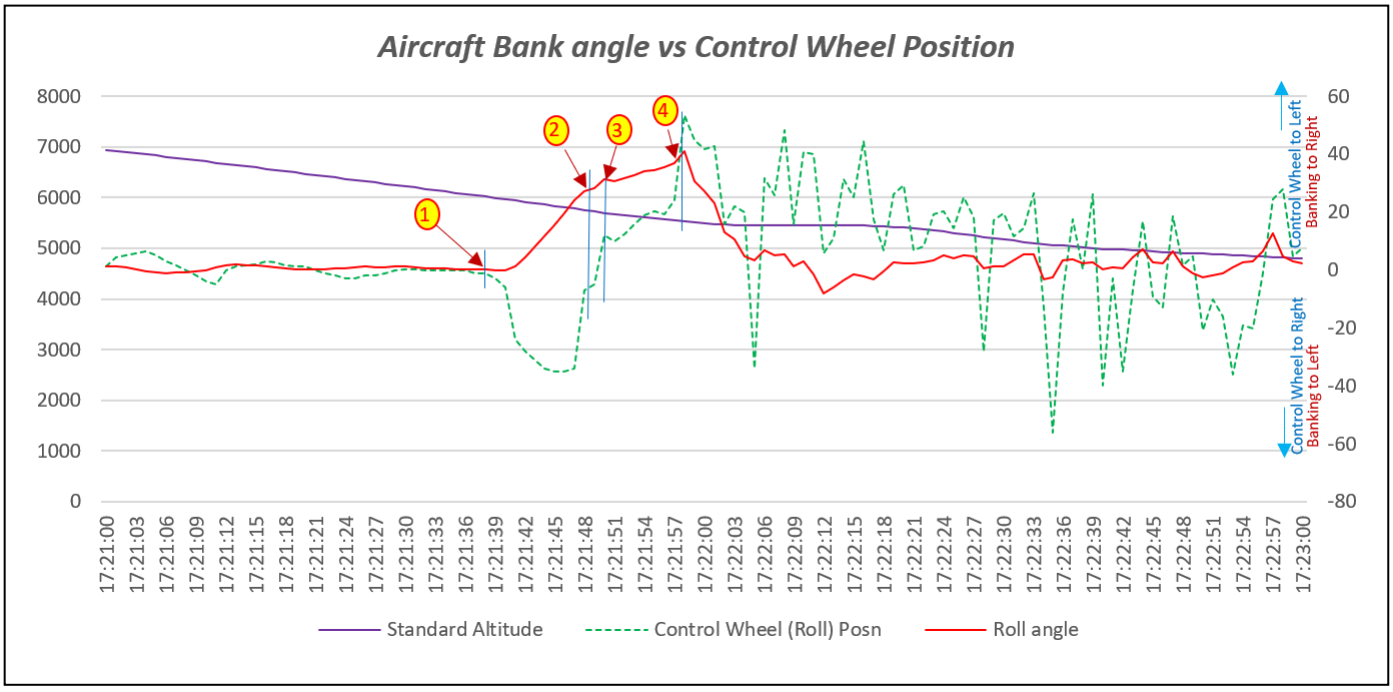


Fig.6: Graph depicting the aircraft bank angle vs the control wheel position

Thereafter, as the aircraft continued descend, at 17:22:29 UTC, power lever #1 (P/L#1) was brought to flight idle while P/L#2 was advanced. At 17:22:44 UTC, selected altitude was set as 3800 ft. While passing 4655 ft, at 17:23:19 UTC, the condition lever of #1 propeller (C/L#1) was feathered. At approx. 17:24:26, the crew descended below 3800 ft.

At 17:32:50 UTC, as the aircraft was 701 ft AGL, Y/D was disengaged and as the aircraft passing 429 ft AGL, at time 17:33:06 UTC, master warning was recorded for 03 seconds. At around 17:34:01 UTC, aircraft touch down safely at RWY 27.

1.11.2 CVR

Relative Time	Observation
01:39:42	LLR658 asked ATC for any chance of giving priority to them for landing citing technical issue. The ATC denied for descend citing traffic ahead. Crew asked if ATC can accommodate them little early to which ATC replied that they are trying their best.
01:40:23	Due to the vibrations, PIC told that they will maintain 170 kts and took over the controls. FO informs that they will not get into the weather but will circumnavigate it.
01:42:13	ATC (APP-ARR) clears LLR658 for a descent to FL060.
01:42:23	PIC says that he will keep low torque/low power due to vibrations. FO discusses that the reason could not be due to weather as the weather patches was not present at that moment.
01:42:34	PIC disconnected the A/P. When FO says should the speed be reduced to 160, PIC says he will sort out the issue first and informs the FO to ask request ATC for a priority landing. The same was accorded by the ATC and instructed the aircraft to turn right heading 180.
01:43:08	ATC clears LLR658 for a descent to 3800 ft on QNH 1004. PIC informs FO to position the C/L#1.
01:44:18	PIC enquires which level the ATC has given to which FO replies '3800'. As informed by PIC, FO asks for a left heading and ATC gave left heading 180.
01:44:38	PIC enquires whether it (vibrations) is from LH engine to which FO says can't confirm.
01:45:04	PIC informs FO to declare PAN PAN. ATC acknowledges the same. ATC gave heading 210. As told by the FO, PIC sets QNH 1004. When FO asked whether he should try A/P, PIC said "No A/P". ATC informed the crew to maintain 3000 ft after observing the descend of LLR658.
01:47:18	PIC briefs CCIC that they are having technical issue and is on single-engine. No need to brace.
01:47:44	ATC informs the crew to turn right heading 220. Localizer alive. LLR658 informs ATC that no assistance required when requested by ATC.
01:49:18	PIC says the vibration is still there to which the FO affirms and says he don't think its because of Engine. FO further says if required can turn it back the engine as they are on low power. PIC says not required as the speed is being maintained.
01:50:09	FO informs ATC that they are on localizer. PIC says vibrations is still present to which the FO said low vibration is due to low speed and not because of engine. Glide alive. Go-around altitude was set.
01:51:25	Transferred to Tower Control. ATC (TWR) informed to continue approach. LDG lowered. Crew discusses that they will land and vacate runway after which they will see.
01:52:42	ATC clears the aircraft to land. Landing checklist carried out by FO. PIC informs FO to disengage Y/D.
01:53:42	After 500 ft RA callout, Master Warning triggers and surprises PIC. FO

	says “Leave it, its Fire”. FO says will check it after landing. Transmits on R/T “LLR658 engine on fire”. TWR coordinates with the Fire Tenders and FMe. 200 ft RA callout. Full emergency declared by ATC.
01:55:19	After landing and vacating via RET N8. FO says “Fire is gone” before vacation.

1.12 Wreckage and impact information

Nil

1.13 Medical and pathological information

Prior to operating their first sortie of the day, both the cockpit crew had undergone BA test and the results were found negative.

1.14 Fire

There was no fire before, during or after the incident.

1.15 Survival Aspects

The incident was survivable.

1.16 Tests and research

1.16.1 I/O module card of CAC 1 shop report

The replaced I/O module card (P/N: C13216BA, S/N: C13216061429) was sent to OEM (M/s Thales) workshop for component testing and repair. The equipment passed all functional acceptance test and no faults were found. Final acceptance test and inspection was also done on automatic testing bench.

1.16.2 Investigation of A/P Roll Actuator Servomotor by M/s Thales

The replaced A/P roll actuator servo motor (S/N: 2016) was sent to an OEM (M/s Thales) workshop for component testing and repair. The visual and functional test on the servo motor revealed the following findings:

- *Jerky running during the bench test*
- *Corroded connector*
- *Continuity out of tolerance*

Following comments were given by M/s Thales based on the shop findings:

Workshop Finding	Comments on the findings
Jerky running during the bench test	- It is an audible oscillation of the actuator shaft. - This is resulting from a contact loss at the potentiometer track, combined with excessive radial mechanical play. - The worn potentiometer is the consequence of nominal mechanical movements.
Corroded connector	- Visually, the external part of the connector showed corrosion. - External corrosion does not affect the functioning of the Servomotor
Continuity out of tolerance	- The cable electrical test (electrical grounding versus mechanical grounding) was not compliant. - A not compliant electrical test does not affect the functioning of the cable.

Further investigation on the involved A/P roll actuator servo motor to ascertain its track continuity and setting in relation to both tracks were performed during a bench test by M/s Thales. The test bench report analysis indicates the results are compliant, indicating that the two tracks (track#1 and track#2) are beavering identically. No abnormal findings were made by M/s Thales during bench test.

1.17 Organizational and Management Information

Alliance Air Aviation Ltd. (Alliance Air) is an airline holding a valid Air Operator Certificate no. S-8 issued by DGCA. It operates a fleet of ATR 72-212A aircraft. The airline has its main operating and maintenance hub at Indira Gandhi International Airport, New Delhi.

The line and base engineering maintenance activities of Alliance Air aircraft's are outsourced to Air India Engineering Services Ltd. (AIESL) which is a DGCA approved CAR 145 organization. Alliance Air has a CAMO setup who monitors the continuous airworthiness requirements of the fleet of aircraft.

1.18 Additional Information

NA

1.19 Useful or Effective Investigation Techniques

Nil

2 ANALYSIS

2.1 Aircraft

2.1.1 Airworthiness of the aircraft

The aircraft had a valid Certificate of Airworthiness and the ARC as on the date of the incident. The aircraft, its engines and propellers were being maintained as per the maintenance program, approved by DGCA. All the concerned AD, mandatory SBs, and DGCA mandatory modifications were complied with as on the date of the incident.

The last major inspection was 9A check which was completed on 25.04.2023 when the aircraft had accumulated approx. 5964:53 FH and 5629 FC. The last scheduled inspection carried out on the aircraft prior to the incident was 400 FH check. There was no abnormality found on the roll control surfaces.

The incident sector was the fourth sector of the day. There was no defect reported prior to departure for the incident sector. The active MEL and DMR entries did not have any contribution to the incident as they were not relevant to the associated aircraft systems.

There was no abnormality or history of defects reported for the vibrations, control surfaces, associated systems, or engines in the past and there were no failure/caution messages or associated maintenance/system-related messages recorded in the computer for the subject incident flight. Hence, the aircraft was considered airworthy.

2.1.2 Deterioration of Roll Control and vibrations during Flight

2.1.2.1 A/P roll actuator

2.1.2.1.1 Investigation by OEM- M/s Thales

The involved A/P Roll actuator servo motor was subjected to investigations in the shop of OEM, M/s Thales. The analysis/ conclusion of the investigation made by M/s Thales, is mentioned below verbatim:

- The removed Servomotor, during tests, showed some out of tolerances values (connector and cable)
  -> Even not compliant, those items do not affect the functioning of the Servomotor.
- The Servomotor being "jerky" indicates a wear of the potentiometer. The shop findings confirmed this wear at zero position. A sustained zero position is equivalent to the aircraft being wings level (bank angle zero). Outside the zero position, the Servomotor is not jerky anymore.
  -> When the aircraft is flying with a bank angle, this Servomotor, is not jerky and does not create vibration.

- According to the tests and the workshop findings, neither malfunction nor vibration could be suspected by the servomotor at a high bank angle. Consequently, it shall not be linked to the observed high bank phenomenon.

In view of the above conclusion made by OEM, the involved A/P Roll actuator servo motor is not considered a contributory factor to the incident.

2.1.2.1.2 A/P roll actuator cable tension

It was found during troubleshooting that the tension of A/P roll actuator cable was below the AMM limits. However, the condition of the cable and the capstan was satisfactory including the cable attachment and wire locking of locknuts. The subject cable was last adjusted on 04.06.2020 during the replacement of the servomotor of the A/P Roll actuator and subsequently, no work was carried out in the aft center section of the wing box. Absence of any abnormal in-situ condition and maintenance records implies that the aircraft was operating with the low cable tension in A/P roll actuator cable since its release after the last replacement of servomotor of the A/P Roll actuator. However, vibrations/ controllability issues were not reported on the aircraft by any of the crew previously.

Considering the discussions outlined in para 2.1.2.1.1 and 2.1.2.1.2, and the conclusion made by the OEM, it can be established that the vibration and controllability issues were not caused by the A/P roll actuator.

2.1.2.2 A/P behavior

The recorded parameters along with the statements of the crew indicates that the control wheel and control surfaces were working normally as per the input given by the A/P. The aircraft was behaving normally during all phases of flight except while taking the right turn, with the A/P engaged, when the ATC was vectoring from the north.

During the right turn, the control wheel was turning to the right and correspondingly the ailerons were deflected as required resulting in a bank angle towards the right. As the bank angle crossed 27 deg, the control wheel started moving towards the left with corresponding movements of ailerons immediately (LH aileron deflection upwards and RH aileron deflection downwards), indicating that the A/P was trying to bring back the aircraft towards neutral or left within its authority. However, even after the control surfaces were moved by the A/P to bring back the aircraft towards neutral/ left, the aircraft continued its right bank, which was later controlled manually by putting significant efforts on the control wheel. The bank angle went upto 41 deg to the right before bringing back the aircraft under control. The A/P did not disengage automatically at any point of time despite the roll exceeding the authority of the A/P.

However, there were no failure/caution messages or associated maintenance/system-related messages recorded in the computer w.r.t. AFCS for the incident flight and the OEMs in their investigation had not indicated any adverse behaviour of the A/P system. In view of the same, the A/P behaviour and/or the A/P servomotor is not considered contributory to the incident.

2.1.2.3 Delamination of the de-icer boot patch

During the troubleshooting, the maintenance staff had identified the delamination of the de-icer boot patch in Zone 616 of the RH wing however the same was not noticed/ recorded in any of the previous sectors.

The RH wing leading edge assembly was sent to the DGCA approved 145 facility for de-icer boot replacement without any clearance from DGCA or the Flight Safety Department of M/s Alliance Air, despite being an incident involved item.

M/s Alliance Air could not provide measurements of the delaminated area of the patch, schematic and/or pictures indicating the exact locations of damage on the boots on the wing leading edge to M/s ATR for their analysis.

As there is no malfunction of such component that would explain the high bank behaviour based on the final investigation report from M/s Thales and based on the data collected related to this event, M/s ATR concluded that the possible root cause of both vibrations and high bank angle phenomena reported on may be the delaminated de-icer boot (zone 616). As per M/s ATR, such damage may have led to aerodynamic perturbations on the RHS Aileron resulting in the vibrations/high bank phenomena. Nevertheless, due to a lack of detailed information as dimensions and extent of the patch on the delaminated area, such a scenario cannot be confirmed by M/s ATR.

2.1.3 Engine Fire Warning during Short Finals

After the aircraft was cleared to land and after disengaging the YD, while the aircraft was at 429 ft AGL, ENG#1 fire warning was triggered. The crew cancelled the same and continued to land.

The fire warning went off automatically after landing and during troubleshooting no abnormality was found on ENG#1. Additionally, inputs from M/s ATR indicated that the fire warning of ENG#1 could probably be due to the low ventilation of the nacelle with the engine running in Flight Idle as the crew feathered propeller#1 10 minutes earlier.

In view of the above discussion, it is concluded that the fire warning on ENG#1 was consequential to the reduced ventilation caused by the feathering of propeller#1, and not a contributory factor to the incident.

2.2 Flight Operations

2.2.1 Crew Qualifications and Training

The license, ratings, trainings and medicals records of the crew were found to be valid as on date of the occurrence. Both the crew were within FDTL limits while operating the incident flight. The PIC and FO had approx. 7100 hrs and 1630 hrs of flying experience on type respectively. Hence, the flight crew were properly qualified and experienced in their respective roles to operate the flight.

2.2.2 Handling of the Flight

2.2.2.1 General

During the pre-flight phase, the crew had briefed about the weather they might encounter. After take-off and as the A/P and Y/D were engaged, the controls were handed over to the FO. As prepared, the weather was encountered during the initial climb onwards. Apart from weather, the fluttering of the tape applied at the LH cockpit fixed window was concerning the PIC. However, this was not discussed with the FO as fluttering ceased subsequently and no deviation in engine parameters were observed.

The crew thereafter received direct routings by the ATC. As the flight was descending, the crew had obtained the weather information and the FO had carried out the approach briefing while passing FL130, which was as per the SOP.

All the standard checklists/ normal procedures were carried out by the crew.

2.2.2.2 Vibrations from LH side

When the aircraft was being vectored, descending passing FL070, the crew felt vibrations from the LH side which were stronger than the normal or weather-related vibrations. The crew discussed about the same and doubted whether the source of the vibration was from LH engine as they were not encountering any weather at that time. Thereafter, the PIC asked for priority due technical issue which was not accorded by the ATC.

Thereafter, the crew discussed to reduce the speed to 170 kts in order to reduce the vibrations, followed by PIC taking over the controls, which is considered appropriate in an abnormal operation. Subsequently, PIC reduced the power of both the engines to idle for an attempt to reduce the vibrations. No indications regarding the airframe vibrations are available at the cockpit deck. The FCOM recommends the crew to identify and shutdown the affected engine followed by feathering the propeller of affected side, in case the vibrations are resulting due to engine or propeller damage; however, in the subject incident the source of vibrations could not be confirmed by the crew. No abnormalities in the engine parameters were noticed.

As the crew were discussing about the vibrations, the PIC observed during the turn that the aircraft banking abnormally and the attention of the crew were focused on the same. Although the power of both the engines were advanced, immediately the power lever angle of ENG#1 was brought to flight idle.

Further discussions regarding vibrations took place after the roll excursion event. After increasing the torque of ENG#2 to ~52%, the LH propeller was feathered. Hence, the actions of the crew to reduce the speed and power were considered appropriate given the limited available evidences to ascertain the actual source of vibrations.

When they were being vectored to capture the localizer and during their final approach, the crew ascertained that the engine was not the cause of vibrations as the vibrations still persisted, although with lower amplitude, at low speed. Nevertheless, the crew continued with the single engine as the source could not be conclusively identified and they were able to maintain the speed. This action by the crew is also considered appropriate to the situation.

2.2.2.3 Roll excursion during heading capture

For the purpose of vectoring from the north, the crew were given a right heading of 160 deg by the ATC when they were on heading 360 deg. As the same was being set on FGCP, the aircraft started rolling to the right with approx. 4 deg/sec. The aircraft banked to more than 27 deg (the A/P limit during turn) and the PIC, at this time, was in discussion with FO regarding the vibrations. There were no failure/caution messages generated when the roll angle exceeded limits of A/P authority.

When the roll angle crossed 27 deg, the control wheel started moving left immediately. The PIC identified the roll excursion 8 seconds after the aircraft crossed 27 deg to the right. At this time, the aircraft was at 39 deg roll to the right, and the PIC had disconnected the A/P followed by applying more effort to the control wheel towards the left roll which was already to the left of its neutral position.

This detection and the immediate action by the PIC had limited the aircraft banking, which had gone up to 41 deg to the right, thereby bringing the aircraft back to a stable attitude. A force of 1013 N on the control wheel was recorded in the DFDR, which implies that the effort made by the crew to manually control the aircraft was substantial.

The crew requested priority landing and the same was accorded by the ATC instructing the crew for further right heading 180 followed by a descent to 3800 ft. The same heading and altitude was set on the FGCP. As the aircraft had faced issue when banking to the right, the crew discussed about requesting a left turn.

Hence when the ATC gave right heading 190, the crew informed to standby, as they were on heading 060, which was acknowledged by the ATC.

2.2.2.4 Reaction to Engine Fire Warning

The engine#1 fire warning was triggered when the aircraft was on short finals to RWY 27 at 429 ft AGL. As soon as the master warning was triggered, the FO cancelled the warnings and when enquired by the PIC, he informed that it is engine fire warning, thereafter the FO informed to leave the matter for concentrating on landing. The ATC was also informed by the FO about the engine fire. The aircraft was handled properly by the crew despite the warning at the critical phase. It was during taxiing after vacation, the crew identified that the warning was no longer in the EWD, thereby informing that they are able taxi to the allotted bay. Hence, the actions of the crew were considered to be satisfactory.

2.3 Icing conditions

The aircraft was flying at an altitude of 5970ft and TAT was 23.5 deg C when it was performing right turn. The local forecast for 100 NM around Mumbai indicated that the freezing level would be approx.17224 ft. There was no snags or defects related to de-icing system during the flight. Icing conditions were not identified and reported by the crew during abnormal behavior of the aircraft. Hence, it could be established that the vibrations and controllability issues faced by the crew were not because of icing conditions.

3 CONCLUSION

3.1 Findings

3.1.1. The Airworthiness Review Certificate of the aircraft was valid and the aircraft was maintained in accordance with the approved maintenance program. The aircraft was airworthy before the release for incident flight.

3.1.2. The license, ratings, trainings and medicals records of the crew were found to be valid as on date of the occurrence. The flight crew were properly qualified and experienced in their respective roles to operate the flight.

3.1.3. After take-off, the controls were handed to FO. PIC was the PM thereafter.

3.1.4. While descending passing FL070, the crew felt abnormal vibrations from the LH side. The PIC took over the controls and reduced the power of both engines to idle in an attempt to reduce the vibrations. No indications regarding the airframe vibrations are available in the cockpit. No abnormalities in the engine parameters were noticed.

3.1.5. While capturing heading, the PIC identified the roll excursion (aircraft roll beyond A/P roll authority) when the bank angle was deg 39 right and the control wheel was moving left. The PIC disconnected the A/P followed by applying significant effort to the control

wheel. This detection and the immediate action by the PIC had limited the aircraft banking.

3.1.6. The aircraft banked up to 41 deg to the right before bringing it under control. Heavy force was applied by the crew to correct the aircraft's attitude towards the left.

3.1.7. During final approach, the crew ascertained that cause of vibrations probably not being from the engine. Nevertheless, the crew continued with the single engine as the source could not be conclusively identified and they were able to maintain the speed.

3.1.8. The control surfaces were working normally as per the input given by the A/P until taking the right turn to capture heading, with the A/P engaged, when the ATC was vectoring from the north.

3.1.9. Low A/P roll actuator cable tension was not contributory to the incident.

3.1.10. An investigation report on the involved A/P roll actuator servo motor from OEM, M/s Thales, concluded that neither malfunction nor vibration could be suspected by the servomotor at a high bank angle. Consequently, it shall not be linked to the observed high bank phenomenon.

3.1.11. During the troubleshooting, the delamination of the de-icer boot patch in Zone 616 of the RH wing was identified, however, the measurements of the delaminated area of the patch, schematic and/or pictures indicating the exact locations of damage on the boots on the wing were not appropriately recorded/preserved by the maintenance staff.

3.1.12. The RH wing leading edge assembly was sent to the DGCA approved 145 facility for de-icer boot replacement without any clearance from DGCA or the Flight Safety Department of M/s Alliance Air, despite being an incident involved item. Hence, the detailed information, such as dimensions and extent of the patch on the delaminated area of the de-icer boot, could not be sent to the OEM for further analysis.

3.1.13. M/s ATR concluded that the delaminated de-icer boot (zone 616) may have led to aerodynamic perturbations on the RHS Aileron resulting in the vibrations/high bank phenomena. Nevertheless, due to lack of detailed information as dimensions and extent of the patch on the delaminated area, such scenario cannot be confirmed.

3.1.14. Fire warning on ENG#1 at short finals was consequential and not a contributory factor to the incident.

3.1.15. Icing conditions did not exist during abnormal behaviour of the aircraft.

3.2 Causes

The delaminated de-icer boot (zone 616) is identified to be the most probable cause of vibrations, controllability issues and high bank phenomena encountered by the cockpit crew. However, due to lack of detailed information such as dimensions and extent of the patch on the delaminated area, the cause cannot be conclusively determined.

4. SAFETY RECOMMENDATIONS

As deemed necessary by DGCA Hqrs based on the above findings.

Digitally signed by Vaishnav Vijayakumar
Date: 2024.11.07 13:19:25 +05'30'

(Vaishnav Vijayakumar)
Member- Investigation, VT-RKM

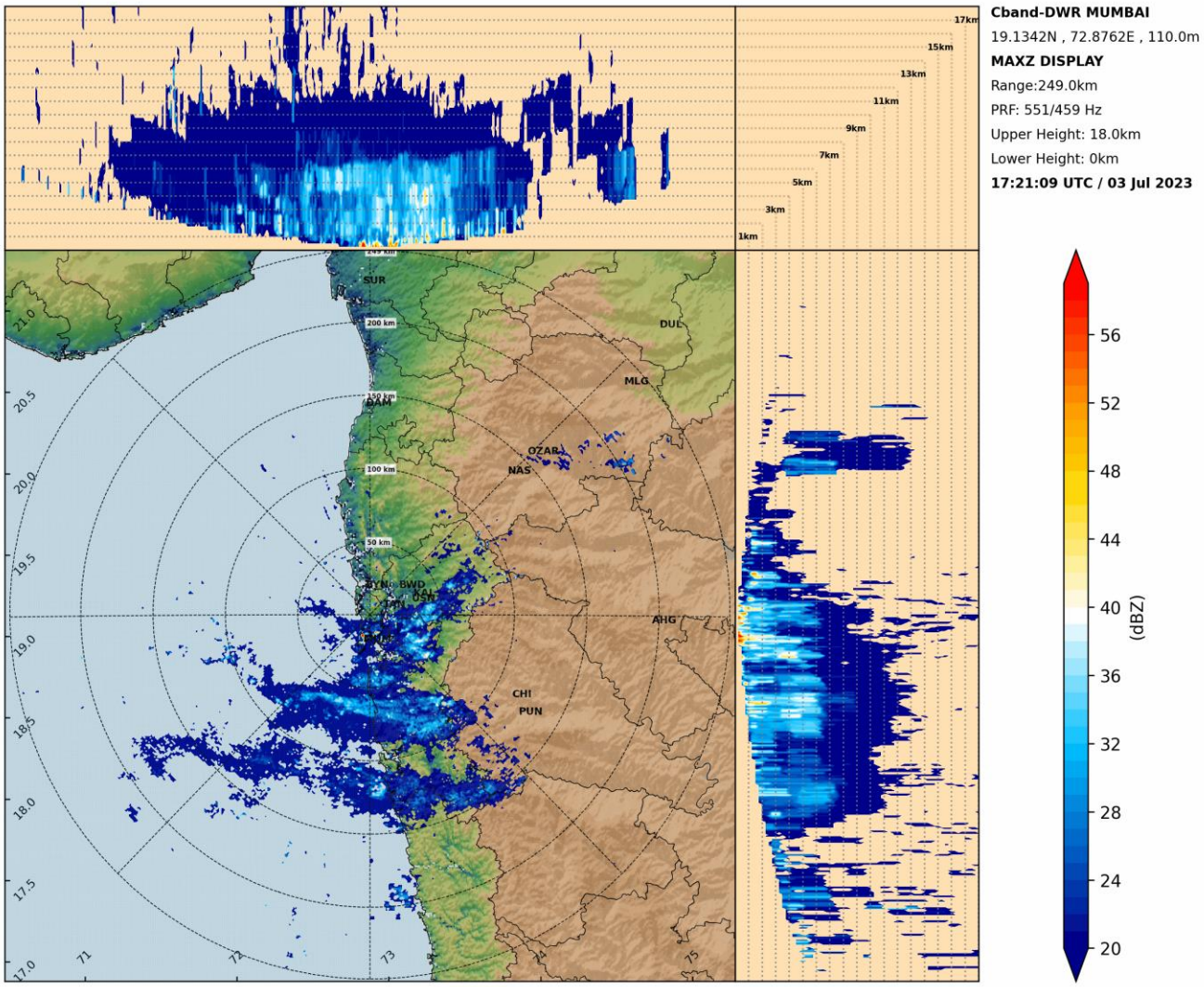
Digitally signed by Pathik Vaghela
Date: 2024.11.07 14:13:42 +05'30'

(Pathik Vaghela)
Investigator In-Charge, VT-RKM

Date: 07.11.2024
Place: Mumbai

ANNEXURE-I

- DWR image product obtained from the IMD



ANNEXURE-II

THALES AVIONICS SA
105 avenue du Général Eisenhower
31 036 TOULOUSE Cedex 1
France
www.thalesgroup.com

Toulouse, July, 25th, 2024

Ref: 0001-0061203267

INVESTIGATION REPORT			
~~FIRST FIT~~	OPERATION	~~PRODUCTION~~	~~AUTRE~~ :

FLIGHT	**AIRCRAFT**
Flight number: 91658 Route: GOA- NUMBAI Date: July 3rd 2023	ATR MSN 1463 IMMAT : VT-RKM

SHORT DESCRIPTION OF THE EVENT

On July 3rd, 2023, Aircraft was in descent with AP engaged.

At 17:21:40 the selected heading was changed from 000° to 161° (right turn), Ailerons were deflected and maintained in a right turn order and the roll angle increased. In accordance with the heading change.

At ~25° of roll angle PL were moved forward by 10° then PL1 was reduced at FI It lead to a torque2 (13%) > torque1 (1%)

Then the roll angle increased up to +30° then +40°

AP disengaged and remained disengaged until landing.

REMOVED UNITS

Auto pilot Servo-Motor (APSM)
P/N C18427BA
s/n 2016

I. Servo motor workshop report

I.1. P/N C18427BA; sn 2016

THALES

WORKSHOP REPORT

Notification : 3824456 *Date: 16.AUG.2023*

Customer : ATR (AVIONS DE TRANSPORT RE
Purch. order : 9800132030
Date : 09.AUG.2023

P/N IN : C18427BA:F9111
S/N IN : 2016
Amdt IN : None

TSN : UNK H
TSO : UNK H
TSR : UNK H
CSN : UNK
CSO : UNK

P/N OUT : C18427BA:F9111
S/N OUT : 2016
Amdt out : None

Container type : Package not reusable
Packaging :

Exam. type :
Devis : NO

Cust. P/N :
Description : SERVOMOTOR

Container : Wedge foam+ paper (+ b
Seals : Seals intacts
ESD protection :

Release Cert :
CAA United Kingdom
EASA / FAR Part 145

Air. Type : ATR72-600
Air. Num : ATR72-600/1463
Air. Regist. : VT-RKM

REASON OF REMOVAL Date of removal : Unknown
Reason for removal: Repair - Unscheduled removal
Operational test of AP Servo actuator not satisfactory
Additional comments : MSN1463 - ATR 72-600 UNDER PBH

PO/RO Review : RPA FR
Notif : 3824456

INVESTIGATIONS (visual and functional)
Jerky running during the bench test
Corroded connector
Continuity out of tolerance

CORRECTIVE ACTIONS : RE Repaired
LRU cleaning.
LRU name Servomotor PN C18427BA SN 2016 repaired by replacing component(s) to completely correct failure.
Performed Final Acceptance Test and Inspection per CMM , on automatic testing bench.

TASK IN ACCORDANCE WITH REASON OF REMOVAL : YES

REFERENCE DOCUMENT
CMPL 22-13-71 REV06 MAR 30/2023

ITEMS REPLACED

Part Number	Description	Location	Serial Number	Qty	Batch	Stat Nav
A1247959	RING,SEALING			1	1508233	-
A2015310	SPACER,HEATSINK			2	1412743	-
A1253610	WASHER,LOCK SST DIA 6.35			4	1652528	-
A1253612	SCREW,MACH STL CD 1/4-28 UNF-3A LGTH 5/8			4	1061882	-
A1235702	SCREW,MACH SST DRILLED FIL H FLAT M2.5X6			15	1637084	O
F2000147	LABEL,SEALING			2	1596331	O
A1170410	WASHER,FLAT SST DIA 2.5			15	1686854	-
A1171536	CLAMP			2	1402548	-
F1361366	CABLE,EQUIPPED			1	1724719	O
A2019116	RESISTOR,VARIABLE 4.7KOHM PM20PCT		23301645	1	1713312	-
A1246255	CONTACT			6	1693620	-

I.2. Shop findings

I.2.1. "Jerky running during the bench test"

It is an audible oscillation of the actuator shaft.
This is resulting from a contact loss at the potentiometer track, combined with excessive radial mechanical play.

The worn potentiometer is the consequence of nominal mechanical movements.
A worn potentiometer is replaced.

I.2.2. "Corroded connector"

Visually, the external part of the connector showed corrosion.
A corroded connector is replaced.

External corrosion does not affect the functioning of the ServoMotor

I.2.3. "Continuity out of tolerance"

The cable electrical test (electrical grounding versus mechanical grounding) was not compliant.
The cable is replaced

A not compliant electrical test does not affect the functioning of the cable

I.3. Servo Motor Test bench report

I.3.1. Setting in relation to both tracks

		Valeurs demandées Expected value		Valeurs relevées Actual value
8.8.3	**- Calage relatif des deux pistes** Setting in relation to both tracks Alimentation consigne = 0V Command voltage = 0V |VPOS1 - VPOS2|	<0.087	V	0.013
	Alimentation consigne = 2V +/- 0,020V Command voltage = 2V +/- 0.020V |VPOS1 - VPOS2|	<0.087	V	0.005
	Alimentation consigne = -2V +/- 0,020V Command voltage = -2V +/- 0.020V |VPOS1 - VPOS2|	<0.087	V	0.006
	Alimentation consigne = 7.2V +/- 0,050V Command voltage = 7.2V +/- 0.050V |VPOS1 - VPOS2|	<0.130	V	0.008
	Alimentation consigne = -7.2V +/- 0,050V Command voltage = -7.2V +/- 0.050V |VPOS1 - VPOS2|	<0.130	V	0.035

I.3.2. Track continuity

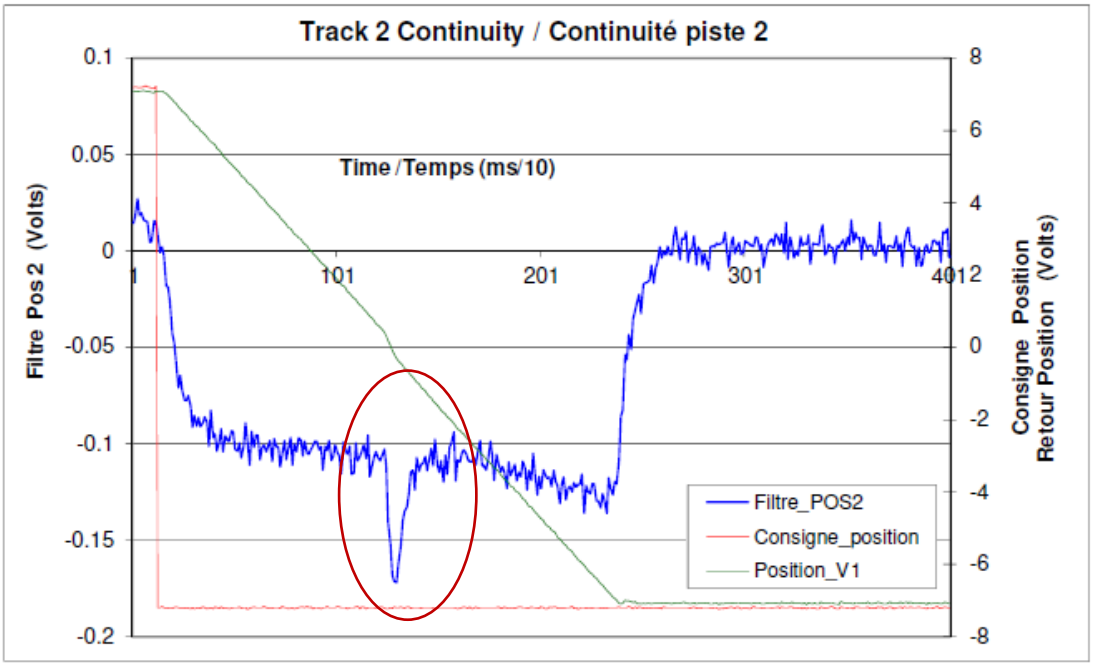
THALES

CAHIER DE RESULTATS D'ESSAIS
TEST RESULTS SHEET

SERVO MOTEUR C18427BA S/N : 2016 **J14754AE 01**

RESULTATS D'ESSAIS SYSTEMATIQUES
RESULT OF SYSTEMATIC TESTS

§ 8.8.1 Continuité Piste 2 / track 2 Continuity



I.4. Test bench report analysis

I.4.1. Setting in relation to both tracks

ATP Test ref. 8.8.3 listed in §I.3.1: the voltage difference is measured between track1 and track2, at different input levels (+/- 2V, 0, +/- 7.2V)
The results are compliant, indicating that the two tracks are beavering identically.

I.4.2. Track continuity

ATP Test ref. 8.8.1 listed in §I.3.2: the discontinuity (here in red circle) is a jump in the signal corresponding to a loss of contact between the cursor and the track.

This is the result of a local track wear out, around zero position.

This track continuity test is carried out only on track2. With the previous "*setting in relation to both tracks*" test results, the continuity on track1 can be deduced.

II. Conclusion

The removed Servomotor, during tests, showed some out of tolerances values (connector and cable)
-> Even not compliant, those items do not affect the functioning of the ServoMotor

The ServoMotor being "jerky" indicates a wear of the potentiometer. The shop findings confirmed this wear at zero position.
Sustained zero position is equivalent to the aircraft being wings level (bank angle zero).

Outside the zero position, the ServoMotor is not jerky anymore.

-> When the aircraft is flying with a bank angle, this ServoMotor, is not jerky and does not create vibration.

According to the tests and the workshop findings, neither malfunction nor vibration could be suspected by the servomotor at high bank angle.
Consequently it shall not be linked to the observed high bank phenomenon.