FINAL INVESTIGATION REPORT

SERIOUS INCIDENT (SMOKE IN COCKPIT)
PAKISTAN AVIATORS & AVIATION FLIGHT NST1
GULFSTREAM G-200 AIRCRAFT REG NO. AP-NST
AT AIIAP, LAHORE ON 31 MAY, 2022

SCOPE

At Bureau of Aircraft Safety Investigation Pakistan (BASIP) investigations are conducted in accordance with Pakistan Aircraft Safety Investigation (PASI) Act, 2023 and International Civil Aviation Organization (ICAO) Annex-13.

The sole objective of the investigation and its final report as per above stated regulations is to prevent future accidents / serious incidents / incidents of similar nature without apportion blame or liability. Accordingly, it is inappropriate to use BASIP investigation reports to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for Judiciary and administrative purpose.

This report contains facts, which are based on information which came to the knowledge of BASIP during the investigation up to the time of publication. Such information is published to inform the aviation industry and the public about the general circumstances of civil aviation accidents and incidents.

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ABBREVIATIONS

AIIAP	Allam Iqbal International Airport
AMSL	Above Mean Sea Level
ATPL	Air Transport Pilot License
BASIP	Bureau of Aircraft Safety Investigation Pakistan
DOF	Designated Overhaul Facility
ft	feet
h	Hour(s)
HP	High Pressure
ICAO	International Civil Aviation Organization
IOU	Incident And Occurrence Unserviceability Report
LC	Low Compressor
LP	Low Pressure
NM	Nautical Mile
OEM	Original Equipment Manufacturer
PCAA	Pakistan Civil Aviation Authority
PF	Pilot Flying
R/W	Runway
s	Second (s)
UTC	Universal Time Coordinated

INTRODUCTION

The serious incident was reported by Pakistan Civil Aviation Authority (PCAA) Incident Occurrence and Unserviceability (IOU) Report. The serious incident was notified in accordance with International Civil Aviation Organization (ICAO) Annex-13. The investigation has been conducted by BASIP with support from Transportation Safety Board (TSB), Canada, General Civil Aviation UAE & a Designated Overhaul Facility (DOF) and a review performed by P&WC

SYNOPSIS

On 31 May, 2022, Pakistan Aviators & Aviation (Pvt) Ltd, flight No. NST1, Gulfstream G-200 aircraft, registration No. AP-NST was operating from Allama Iqbal International Airport (AIIAP), Lahore to Heydar Aliyev International Airport, Baku, Azerbaijan with 05 persons on-board.

At time 081145, at position 8 Nautical Mile (NM) north west of Lahore, passing altitude 4,500 feet (ft), pilot declared emergency due to smoke in cockpit. Pilot requested to land back as a precautionary measure. Aircraft subsequently landed safely at AIIAP, Lahore.

Based on available data and analysis of Designated Overhaul Facility (DOF) report, smoke in the cabin was due to improper bearing No.3 compartment sealing including damaged bearing No.3 front carbon seal which allowed oil to migrate into the secondary air system and then through the cabin bleed tubes into the aircraft. Furthermore, signs of oil leakage could be observed at the bearing No.1, Inter-shaft and bearing No.4 carbon seals. The evidence of oil leakage may lead to oil smell (smoke) in aircraft cabin.

In extreme dusty / sandy and polluted environment if engines are not properly maintained in accordance with manufacturer recommendations, rubber seals can get worn out before time leading to oil and air leakages in aircraft systems. In subject case the damage occurred due to accumulation of sand on silicone rubber seal and operations of the aircraft in extreme polluted areas. This resulted in wearing of the rubber seal causing oil leakage into the cabin bleed tubes through the secondary air system. All corresponding timing are mentioned in Universal Time Coordinated (UTC).

SECTION 1 - FACTUAL INFORMATION

1.1. History of the flight

1.1.1. On 31 May, 2022, Pakistan Aviators & Aviation (Pvt) Ltd, flight No. NST1, Gulfstream G-200 aircraft, registration No. AP-NST was operating from Allama Iqbal International Airport (AIIAP), Lahore to Heydar Aliyev, Baku, Azerbaijan with 05 personnel on board.

1.1.2. **081008** – NST1 took off from Runway (R/W) 36L AIIAP, Lahore.

1.1.3. **081145** – When NST1 was 08 NM South West of Lahore, at 4,500 ft Above Mean Sea Level (AMSL), it reported smoke in cockpit and requested priority landing at AIIAP, Lahore.

1.1.4. **081845** – NST1 reported that smoke was dissipating and everything seemed OK.

1.1.5. **082254** – NST1 landed back safely at AIIAP, Lahore.

1.2. Injuries to person(s)

1.2.1. No injury was reported to any person on board the aircraft.

Injuries	Crew	Passengers	Total in aircraft	Others
Fatal	-	-	-	-
Serious	-	-	-	-
Minor	-	-	-	-
None	03	02	05	-
TOTAL	**03**	**02**	**05**	**-**

Table 1 Details of Injuries to Persons

1.3. Damage to aircraft

1.3.1. There was no damage to the aircraft due to smoke in cockpit and aircraft landed safe at the airport.

1.4. Other damages

1.4.1. Not Applicable.

1.5. Personnel information

Pilot Flying	
License type	Air Transport Pilot License (ATPL)
Medical date with status	January 2021, medically fit, Class-I, Valid
Flying experience	6501:45
On type	650:00

Table 2 Pilot Flying (PF) details

1.6. Aircraft information

Aircraft Details	
Operator	Pakistan Aviators & Aviation
Call Sign	NST1
Aircraft Make & Model	Gulfstream G-200
Registration Number	AP-NST
Serial Number	240
Year of manufacturing	2010
Hours since new	1713.3
Engine S/N PCE-CC-0498	
Model	PW306A
Serial Number	CC0498
Date of installation	07 July, 2010
TSN (h(s) / Cycles)	1713.3 / 1021
TSO	N/A

Table 3 Aircraft / Engine Details

1.6.1. Aircraft operating history did not indicate any past defect related to engine or smoke in the cockpit.

1.6.2. Aircraft and engine last scheduled inspection (1C, 2C, 1A, and 2A) were performed at Jet Aviation, Dubai UAE on 08 March, 2022.

1.6.3. Compressor wash of engine No.1 and 2 was last performed on operator request IAW AMM71-00-06 and EMM71-00-00 at Jet Aviation Dubai UAE on 05 March, 2022.

1.6.4. The incident of smoke in cockpit was reported after 19.2 hours (h) since the inspection of 08 March, 2022 at Jet Aviation, Dubai UAE.

1.6.5. Engine No CC0498 was removed from the aircraft after the serious incident and was dispatched to a DOF in Germany where a tear down examination was carried out.

1.6.6. DOF analysis report revealed following: -

1.6.6.1. **Fan of Low Pressure (LP) Rotor Balancing Assembly** - Minor erosion and nicks were found at blade leading edges.

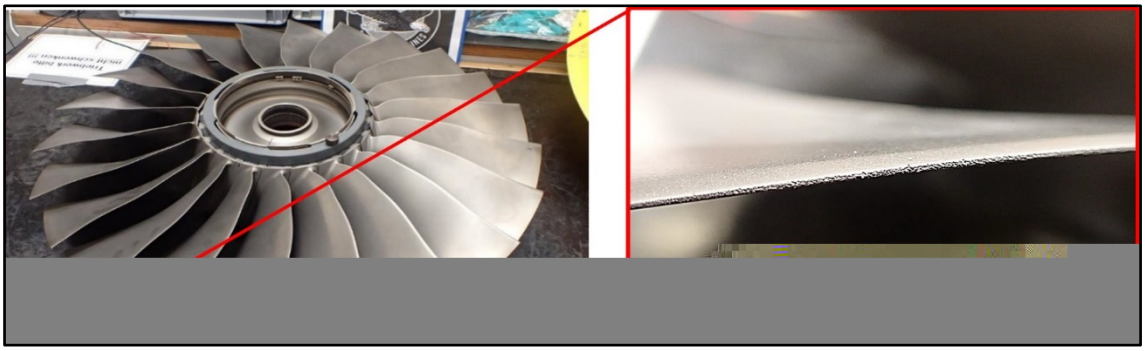

Figure 1 LP Rotor Balancing Assembly (Fan) and Erosion on Fan Edges

Figure 2 Nick Marks on LP Rotor Balancing Assembly (Fan)

1.6.6.2. **Fan Case Assembly**- Deterioration of abradable coating was found.

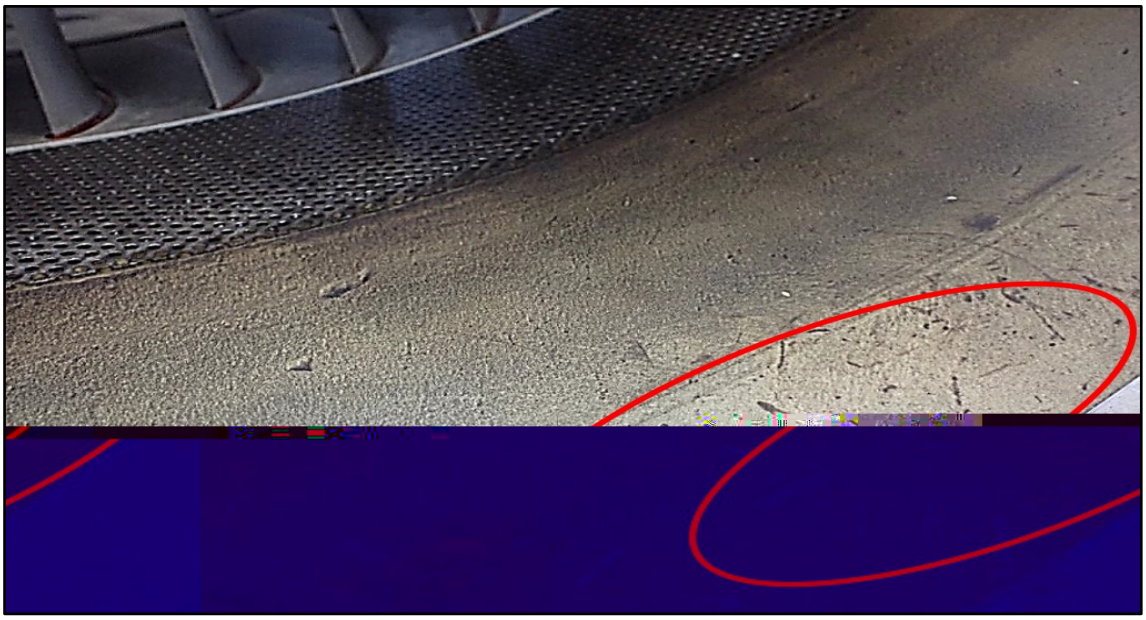

Figure 3 Scratch marks on Fan Case Assembly

1.6.6.3. **Compressor Inlet Cone -** Fretting wear at fan blade contact faces was found.

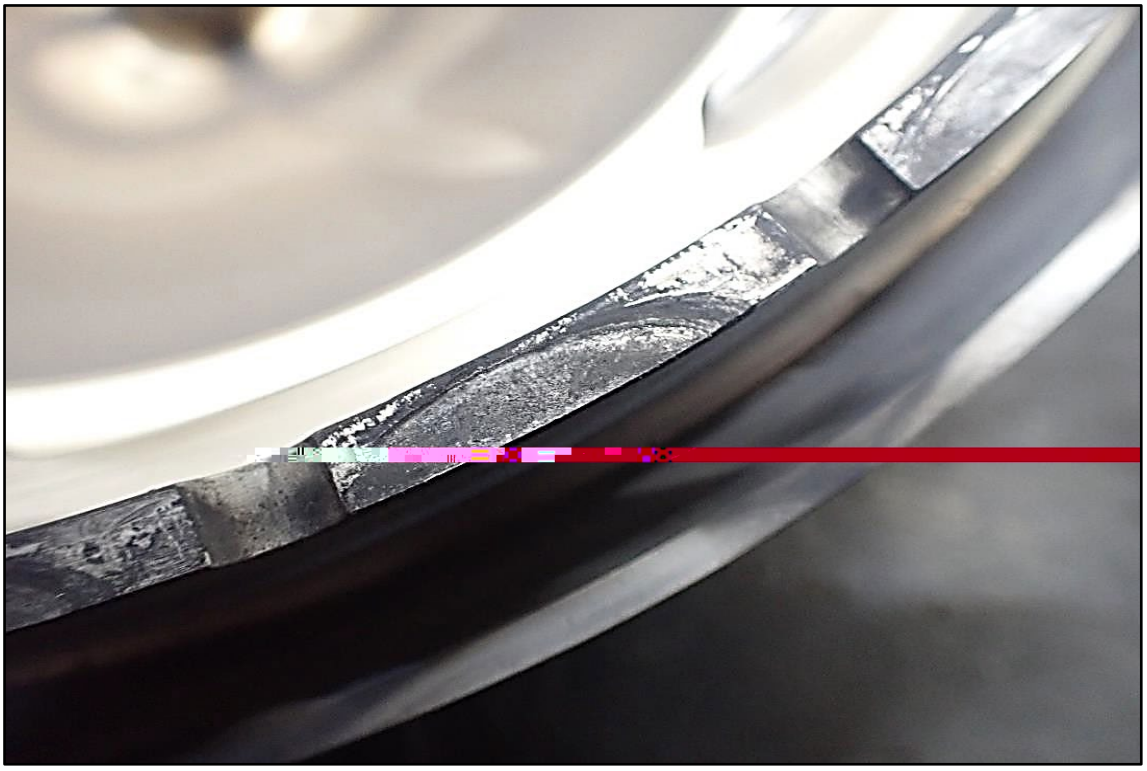

Figure 4 Compressor Inlet Cone

1.6.6.4. **Compressor Inlet Cone –** During investigation traces of oil were found.

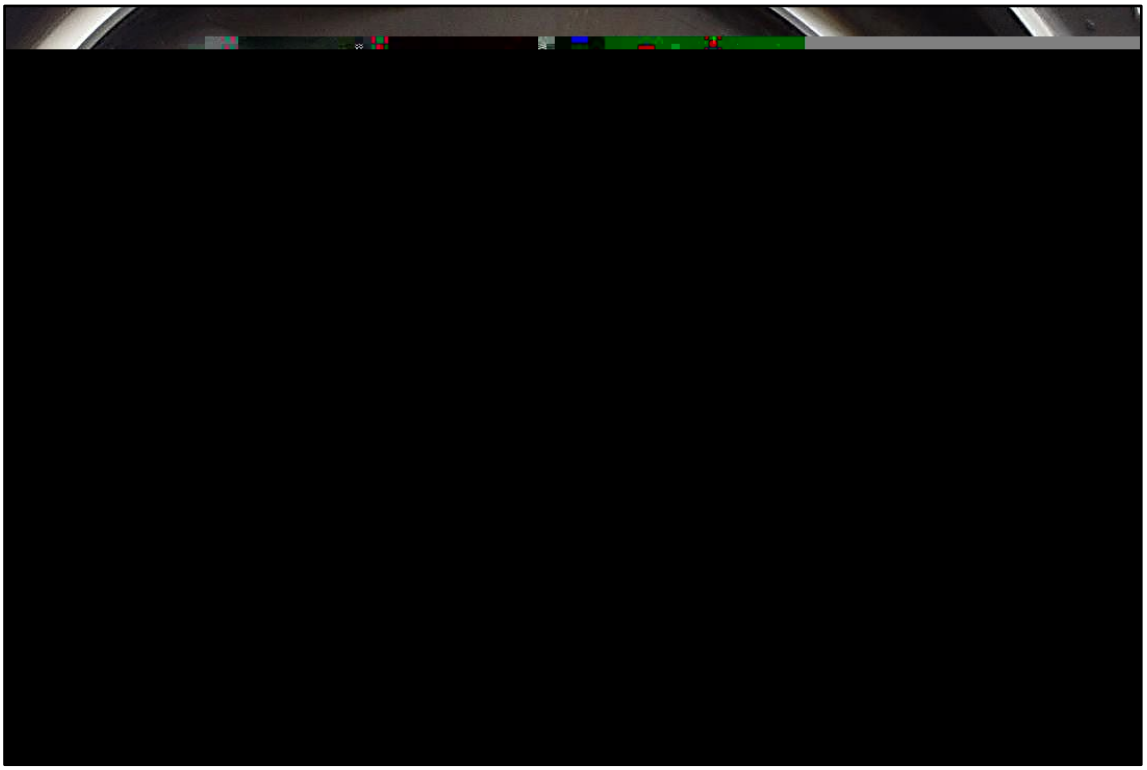

Figure 5 Traces of Oil in Compressor Inlet Cone

1.6.6.5. **Low Compressor (LC) Shaft Assembly –** It was revealed during investigation inner cavity was oil wetted with sandy deposits.

Figure 6 LC Shaft Assembly Rear and Front

1.6.6.6. **LC Shaft Assembly** - Damaged threads were found.

Figure 7 LC Shaft Assembly (close-up)

1.6.6.7. **Compressor Inlet Vane Assembly** - Oil wetted vanes were present.

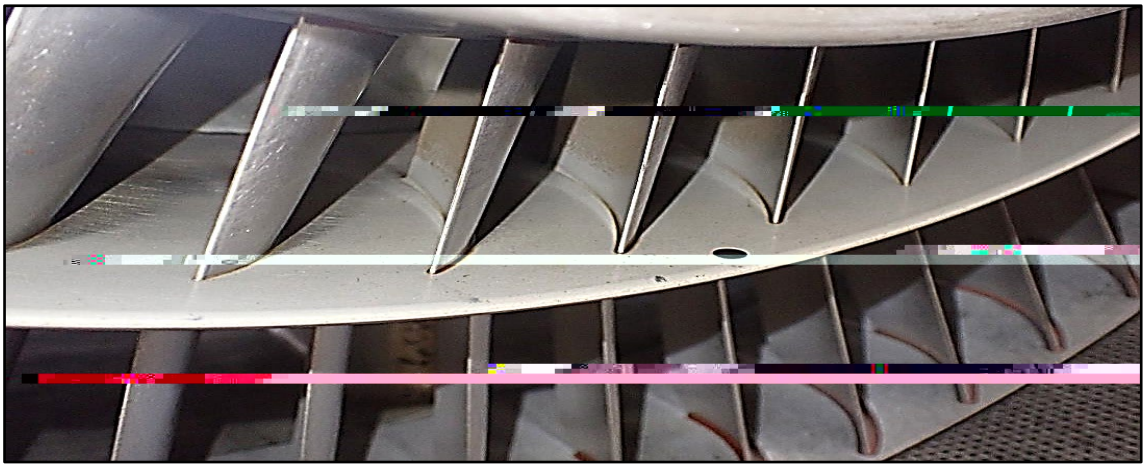

Figure 8 Compressor Inlet Vane Assembly

1.6.6.8. **Compressor Inlet Vane Assembly** - Inner shroud was found oil wetted.

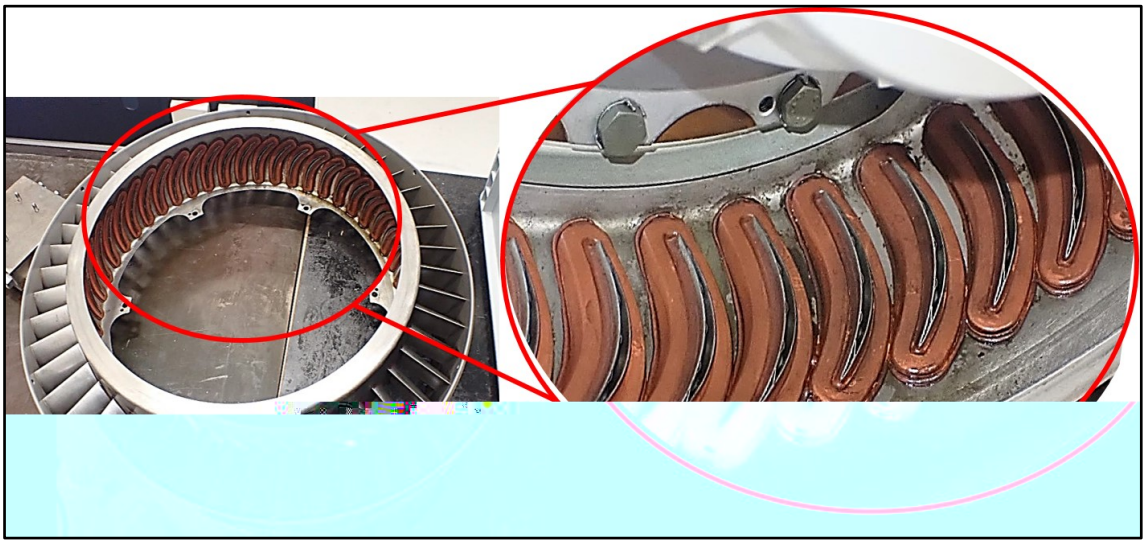

Figure 9 Compressor Inlet Vane Assembly

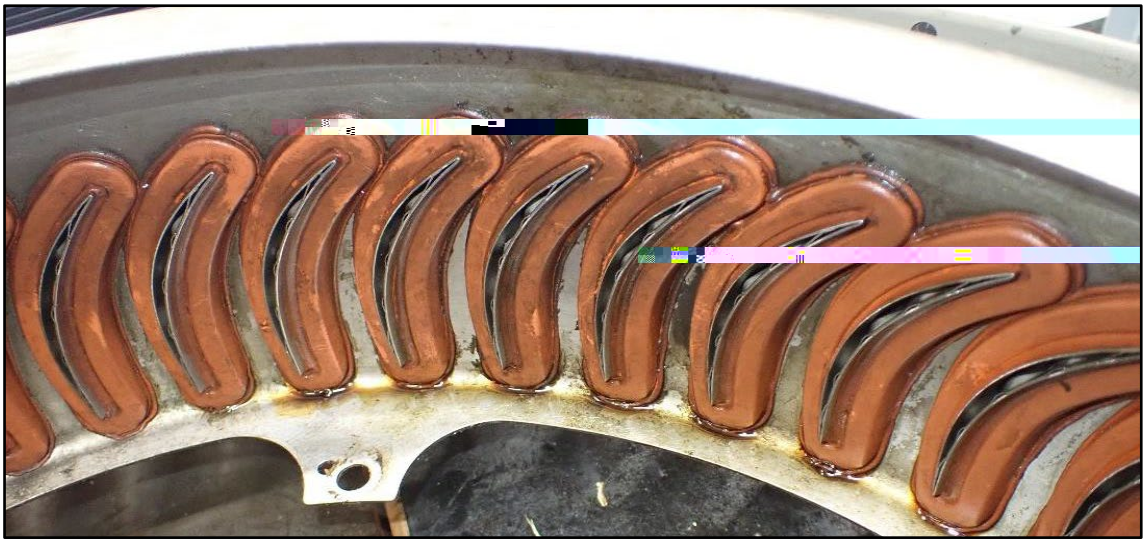

Figure 10 Compressor Inlet Vane Assembly

1.6.6.9. **Bearing No.1 Cover** - Signs of oil leakage was found.

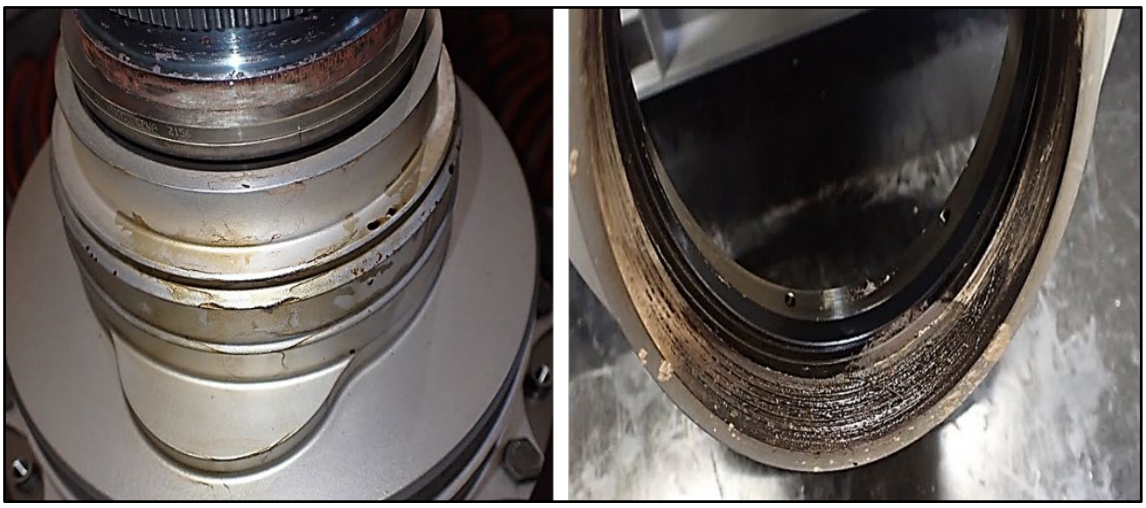

Figure 11 Bearing No.1 Cover

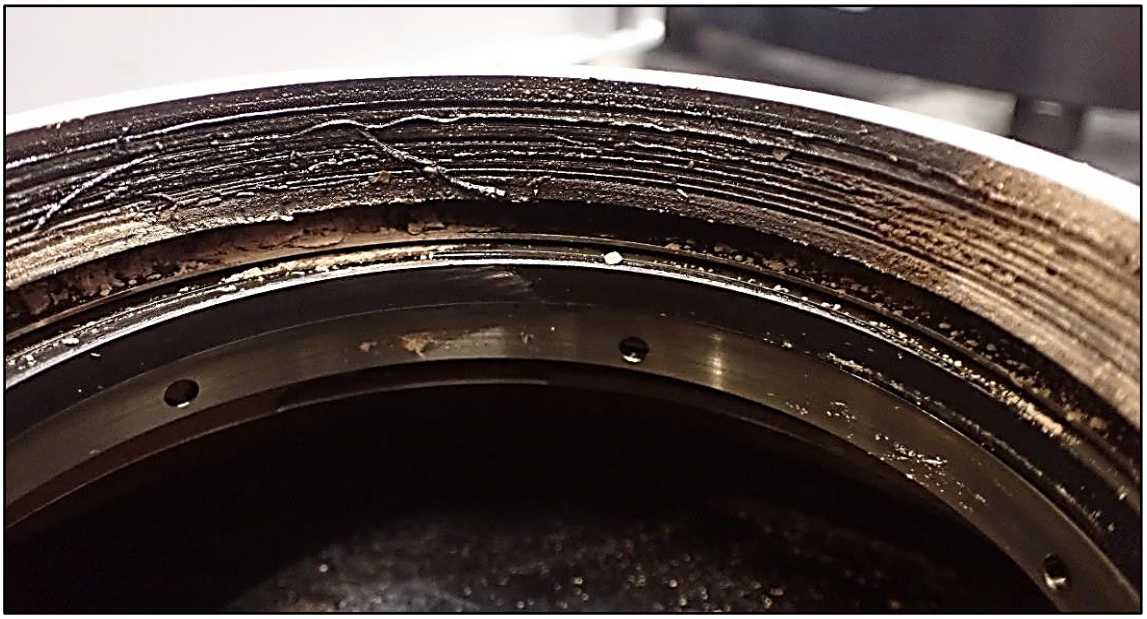

Figure 12 Bearing No.1 Cover close-up view

1.6.6.10. **Inter-shaft Seal Housing Assembly -** Sandy deposits, signs of oil staining were found.

Figure 13 Inter-shaft Seal Housing Assembly

Figure 14 Inter-shaft Seal Housing Assembly

1.6.6.11. **No.3 Bearing Rear Cover Installation** - Oil carbon deposits, signs of oil staining were found.

Figure 15 Bearing No.3 Rear Cover Installation

1.6.6.12. **Bearing No.3 Front Cover Installation** – Oil staining and chips on the edge of the front carbon seal element were found.

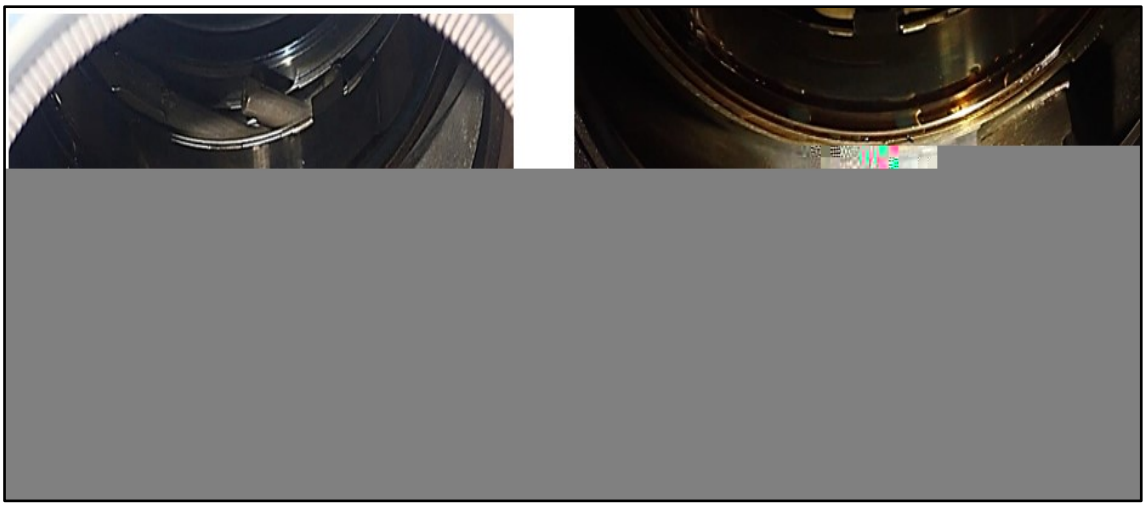

Figure 16 Bearing No.3 Front Cover Installation

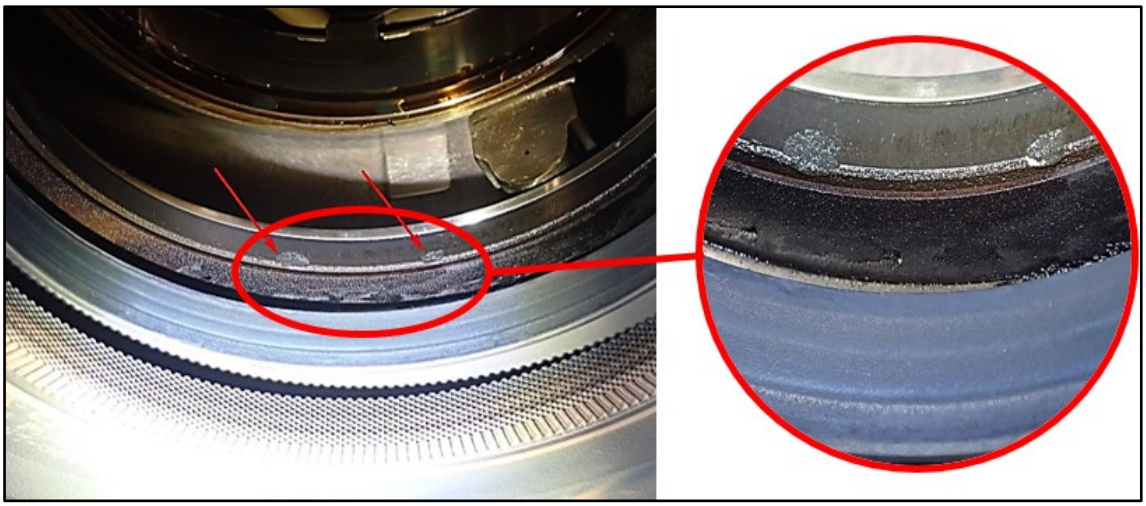

Figure 17 Bearing No.3 Front Cover Installation

1.6.6.13. **Bearing No.3 Front Carbon Seal** - Staining and chips on the edge of the front carbon seal No.3 bearing carbon seal element were found.

Figure 18 Bearing No.3 Front Carbon Seal

1.6.6.14. **High Pressure (HP) Turbine Air Seal (Large Brush Seal)** - Worn bristles was found.

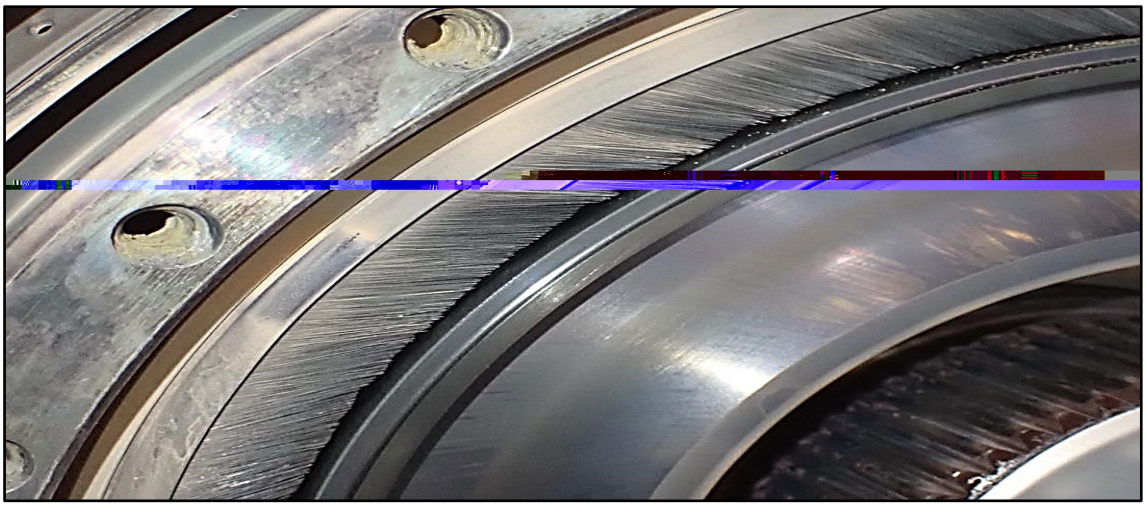

Figure 19 HP Turbine Air Seal (Large Brush Seal)

1.6.6.15. **1st Stage HP Turbine Disk Assembly -** Blade tip rubbing, sandy deposits and coating deterioration were found.

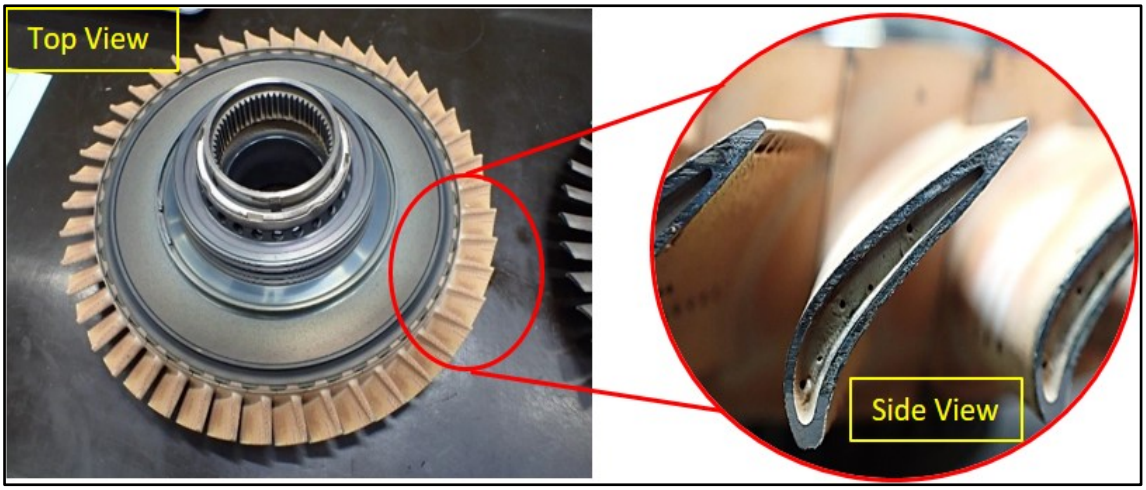

Figure 20 1st Stage HP Turbine Disk Assembly

Figure 21 1st Stage HP Turbine Disk Assembly

1.6.6.16. **Turbine Exhaust Case Assembly** - Signs of oil staining was found.

Figure 22 Turbine Exhaust Case Assembly

1.6.6.17. **BearinNo.4 Carrier -** Cooked oil - oil staining was found

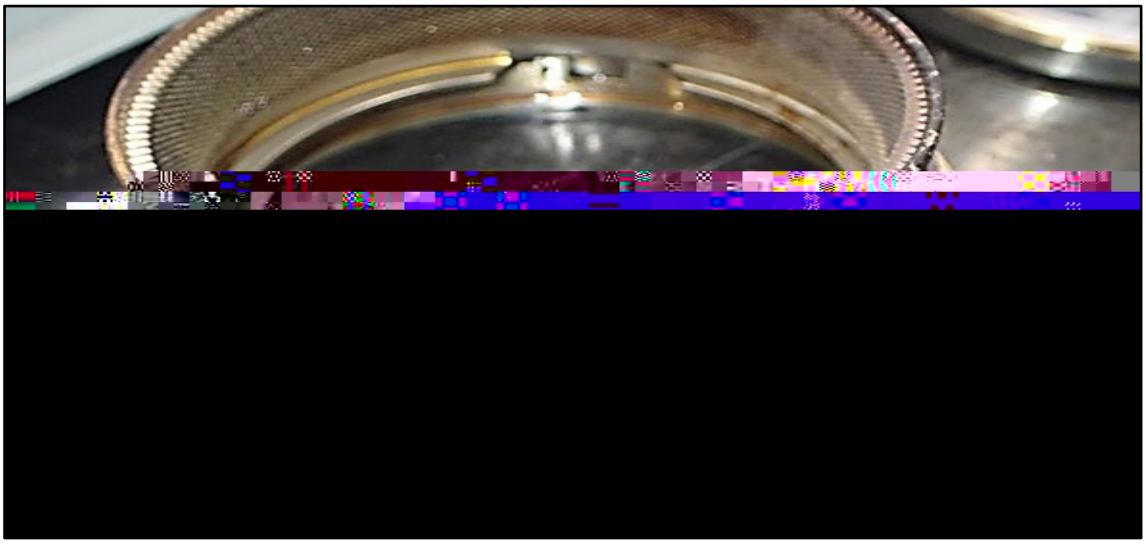

Figure 23 Bearing No.4 Carrier

1.6.6.18. **Bearing No.4 Carbon Seal** - Cooked oil - signs of oil staining was found.

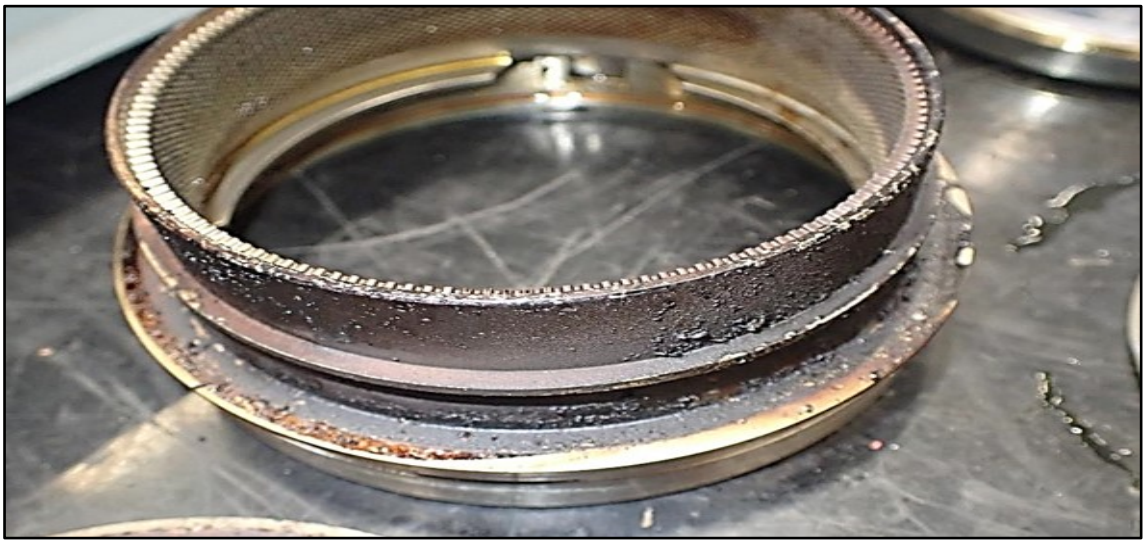

Figure 24 Bearing No.4 Carbon Seal

1.6.6.19. **Main Bearing Carbon Seals** – varying degrees of oil staining at (from left to right) Bearing No. 1 Carbon Seal and two (2) Inter-shaft carbon seals,two Bearing No. 3 Carbon Seal, Bearing No. 4 Carbon Seal.

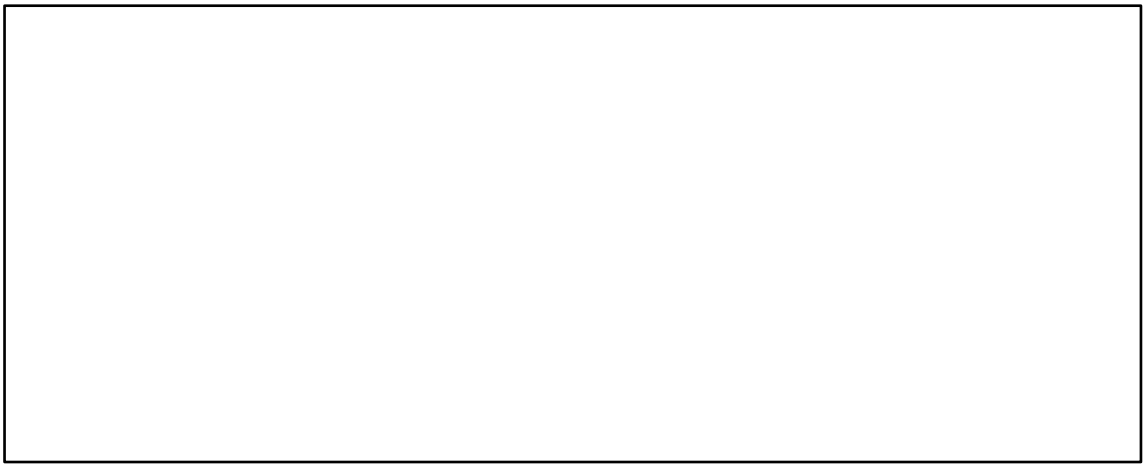

Figure 25 Main Bearing Carbon Seals

1.6.6.20. **Rear Outer B/P Duct** - Rear Outer B/P Duct was found oil wetted.

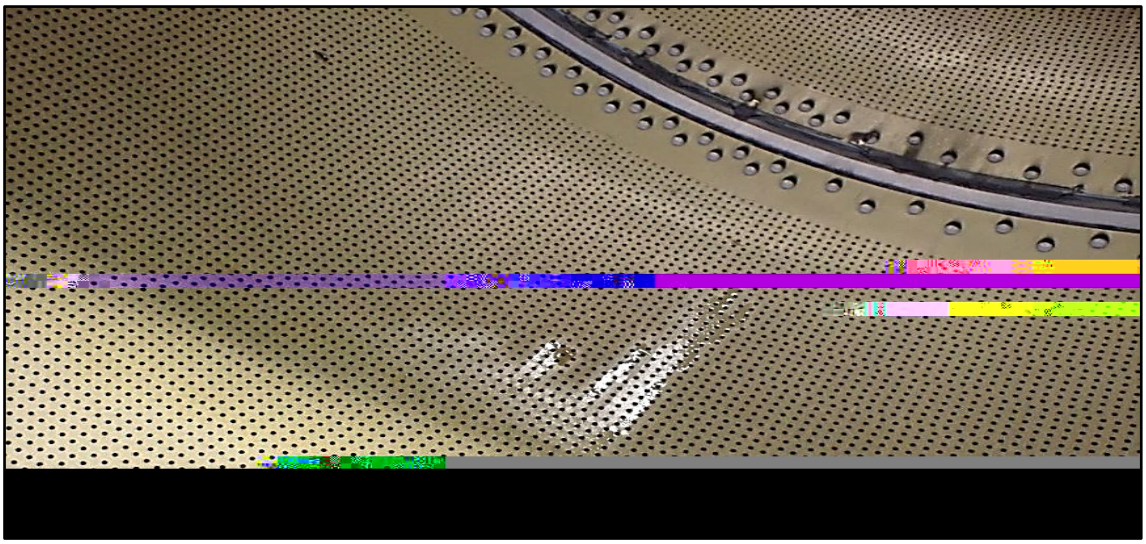

Figure 26 Rear Outer B/P Duct

1.6.7. Oil staining of varying severity was present on the inter-shaft and the No. 3 and No. 4 carbon seals. In addition, localized chipping was observed on the No. 3 bearing front carbon seal element. Inspection identified significant wear and deterioration of the No. 1 bearing cover polymer seal. This condition provided a plausible leakage path for oil migration into the gas path, leading to the smoke in cockpit scenario. The premature degradation of the No. 1 bearing cover polymer seal is assessed to be consistent with prolonged exposure to abrasive particulates, such as sand and pollution, which may have accelerated seal wear.

1.7. Meteorological information

1.7.1. Not Applicable.

1.8. Aids to navigation

TYPE OF AID	ID	Frequency	Hours of operation	Site of transmitting antenna coordinates	Elevation of DME transmitting antenna	Remarks
1	2	3	4	5	6	7
ILS/LOC CAT I 36L	ILO	109.7 MHz	H24	313223.67N 0742410.54E	NIL	NIL
ILS/LOC CAT III 36R	ILA	109.9 MHz	H24	313224.49N 0742417.66E	NIL	Coverage 20 NM
NDB	LA	268.0 kHz	H24	313123.41N 0742348.18E	NIL	NIL
DVOR/DME (2°E/2020)	LA	112.7 MHz CH74X	H24	313109.66N 0742400.05E	227.07M	200NM
MM	-	75.0 MHz	H24	312949.99N 0742414.91E	NIL	RWY 36R
OM	LO	338.0 kHz	H24	312641.15N 0742404.47E	NIL	Locator Outermarker RWY 36R
OM	-	75.0 MHz	H24	312641.50N 0742404.51E	NIL	RWY 36R
GP/TDME 36L	ILO	333.2 MHz CH34X	H24	313042.70N 0742403.86E	235.31M	NIL
GP/TDME 36R	ILA	333.8 MHz CH36X	H24	313033.31N 0742412.15E	231.04M	Coverage 7-10 NM

Table 4 Aids to navigation, AIIAP, Lahore

1.9. Communications

Service designation	Call sign	Frequency	Hours of operation	Remarks
1	2	3	4	5
APP	Lahore APP	121.300 MHZ	H24	Primary
APP	Lahore APP	121.500 MHZ	H24	Emergency
APP	Lahore APP	125.300 MHZ	H24	Secondary
ATIS	ATIS	126.300 MHZ	H24	NIL
BS	Radio Pakistan	630.000 MHZ	HX	0130**1900HR
BS	Radio Pakistan	1090.000 MHZ	HX	Variable SKED
GCA	Lahore Ground	118.400 MHZ	H24	Primary
GCA	Lahore Ground	121.800 MHZ	H24	Secondary
TWR	Lahore Tower	118.100 MHZ	H24	Primary
TWR	Lahore Tower	118.875 MHZ	H24	Secondary

Table 5 Communication Frequencies, AIIAP, Lahore

1.17. Organizational and management information

1.17.1. Not Applicable.

1.18. Additional information

1.18.1. Not Applicable.

1.19. Useful or effective investigation techniques

1.19.1. Standard investigation procedures and techniques were used during the course of investigation.

SECTION 2 – ANALYSIS

2.1. General

2.1.1. This analysis addresses a serious incident involving smoke ingress into the aircraft cabin originating from Engine S/N PCE-CC-0498. The sequence of events, maintenance history, environmental exposure, and post-incident inspections were evaluated. Evidence suggests that the most likely reason for oil smell in cabin was a result of the worn / degraded No. 1 bearing polymer air / oil seal which resulted from an extensive ingress of abrasive particulates. This condition was likely a result of maintenance recommendations, outlined by the P&WC engine maintenance manual, not properly being adhered to.

2.2. Flight Operations

2.2.1. Flight log data showed that the aircraft routinely operated on domestic routes primarily between Lahore, Karachi, and Islamabad, which are classified by the manufacturer as “severe environment” operating conditions due to high dust and pollution levels. The operator reported compliance with a yearly compressor wash schedule; however, the PW306A Engine Maintenance Manual (EMM) recommends that aircraft operating continually or frequently in such environments undergo compressor washes on a weekly or bi-weekly basis, or as indicated by general observations. Although no abnormal engine indications or smoke warnings were reported prior to the incident flight, and the engine had accumulated only 19.2 operating hours since the most recent compressor wash, sand accumulation and oil seepage were observed in the engine areas. These observations suggest that wear of the bearing carbon seals and elastomeric seals may have already commenced. This indicates that, while a compressor wash was performed, the modified wash procedure used by the operator may not have been effective in mitigating the prevailing operating conditions. More frequent compressor washes and enhanced inspections during scheduled maintenance may have reduced the likelihood of the condition developing or enabled earlier detection.

2.3. Aircraft

2.3.1. A review of the maintenance records confirmed that the aircraft was in compliance with its approved maintenance program, with the exception of completing the compressor washes based on the engine manufacturers guidelines outlined by the EMM.

2.3.2. Following the incident, post-flight inspection revealed oil seepage emanating from No. 1 Engine S/N PCE-CC-0498, No.1 bearing cover. The engine was removed and send to a DOF where disassembly was performed. Observations included evidence of oil seepage from the No. 1 Bearing Air / Oil Seal. There were abrasive particulates noted in the No. 1 bearing cover plenum between the polymer and Carbon seal. The polymer seal exhibited smearing and was worn. This condition, could allow for oil leakage into the compressor inlet thus leading to oil smell / smoke condition. Additional observations include oil staining on the known sealing surfaces of the inter-shaft, No. 3 and No. 4 bearing carbon seals. Moreover, there were chips observed on the front No. 3 bearing carbon seal element edge, however, the chips only covered

approximately 40 % of the sealing surface, thus the chips of the No. 3 front carbon seal and the staining observed on the known sealing surfaces of the carbon seals is not considered a contributor.

2.3.3. Additionally, Sand deposits were found in key engine areas including:

2.3.3.1. LC Shaft Assembly

2.3.3.2. No.1 Bearing Area

2.3.3.3. Inter-shaft Seal Housing

2.3.3.4. First Stage HP Turbine Disk Area

2.4. Environmental and Operational Conditions

2.4.1. The aircraft's primary routes, especially between Lahore and Karachi, expose it to significant airborne contaminants such as dust, sand, and industrial pollutants. These factors fall under the "severe environment" classification as per the manufacturer's guidance. While the compressor wash was performed annually or every 500 flight hours by operator, contrary to the manufacturer guidelines that are weekly or bi weekly as per EMM, this may not have been sufficient for the actual operating conditions. The discovery of extensive sand contamination suggests that environmental severity had a direct and measurable impact on engine component degradation.

2.5. Human Factor

2.5.1. No evidence was found to indicate that direct human error contributed to the incident. The flight crew operated the aircraft in accordance with procedures and responded appropriately to the presence of smoke. Maintenance activities were performed at certified facilities, and available records indicated that prescribed procedures were followed except the compressor wash cycle which was modified by the operator. The operator's decision to maintain the modified wash interval, despite increased exposure to environmental contaminants, reflects poor assessment by the operator of environmental factors as provided in the manufacturer guidelines.

2.6. Survivability

2.6.1. The incident did not involve injury or damage beyond the presence of smoke in the cabin. The aircraft landed safely without requiring an emergency evacuation. Cabin systems functioned as designed, and crew response mitigated potential escalation. No survivability issues were identified.

2.7. Organizational and Management Information

2.7.1. The operator had implemented a compressor wash schedule of 500 flight hours or during 1C checks, for which a No objection email was sought from the aircraft manufacturer. No additional risk mitigation strategies were applied to account for the aircraft's operating environment. This indicates that the operator's maintenance

program lacked adaptability to changing operational risks. Environmental operating conditions were known and documented but were not sufficiently factored into maintenance escalation or monitoring strategies.

SECTION 3 – CONCLUSIONS

3.1. Findings

3.1.1. General

3.1.1.1. The aircraft had no recorded history of engine-related defects or cockpit smoke prior to the incident.

3.1.1.2. The last scheduled maintenance inspections (1A, 2A, 1C, and 2C) and compressor wash were carried out at an approved maintenance facility (Jet Aviation, Dubai, UAE) in March 2022.

3.1.1.3. A serious incident involving smoke in the cabin occurred only after 19.2 flight hours and 13 flights following the last compressor wash.

3.1.1.4. The aircraft operated in a “severe environment” (high dust/pollution levels), this along with the fact the operator did not follow the EMM recommended maintenance procedures regarding compressor wash schedule, likely led to premature degradation of the No.1 bearing polymer seal.

3.1.1.5. Disassembly inspection revealed the main source of oil leakage from the No.1 bearing polymer seal. Additional oil staining was noted on various other mainline seals; however, the staining was not located at the sealing surfaces and is not believed to be a contributing factor in the event.

3.1.1.6. Sand deposits were identified in multiple internal engine components, including the LC Shaft Assembly, Bearing No.1 area, inter-shaft seal housing, and the first stage HP turbine disk area.

3.1.1.7. The smoke ingress into the cabin was a result of a worn / degraded No.1 bearing air / oil seal, which resulted from an ingress of abrasive particulate.

3.1.1.8. The Engine Maintenance Manual (EMM) classifies the aircraft’s operating environment as “severe” and recommends that compressor washes be performed on a weekly or bi-weekly basis. The operator implemented a modified compressor wash interval of 500 flights or one C check. This interval did not reflect the environmental considerations specified in the manufacturer’s guidelines.

3.1.2. Organizational Factors

3.1.2.1. The operator followed a modified maintenance schedule of 500 flight hours or 1C check intervals for compressor washing, contrast to the weekly or bi-weekly cycles defined by the manufacturer-approved procedures.

3.1.2.2. The operator’s maintenance program lacked condition-based adjustments despite known environmental risks.

3.1.3. Human Performance

3.1.3.1. No direct human errors were identified.

3.1.3.2. The flight crew responded appropriately to the smoke event, ensuring a safe landing.

3.1.4. **Survivability**

3.1.4.1. Cabin systems functioned as designed, and no injuries occurred.

3.2. Causes / Contributing Factors

3.2.1. **Cause**

3.2.1.1. The premature wear of the No.1 bearing cover air / oil seal due to exposure to a severe dusty and polluted environment permitted ingress of oil into the gas path.

3.2.2. **Contributory Factor**

3.2.2.1. The unusual amount of abrasive particulate deposits in the engine particularly in the LC Shaft Assembly, Bearing No.1 area, inter-shaft seal housing, and first stage HP turbine disk could have been mitigated by following the engine manufacturers compressor wash schedule as outlined by the EMM 30B1412.

3.2.2.2. The aircraft frequently operated in a severe environment characterized by dust, sand, and air pollution, especially along routes such as Lahore, Karachi and Islamabad.

3.2.2.3. Operators' decision to modify the wash cycles without fully analyzing the severe dust and polluted environment and failure to incorporate adaptive maintenance strategies to address the increased wear resulting from these harsh environmental conditions.

Note: Aviation Occurrence Category (ADREP Taxonomy)
FIRE/SMOKE (NON-IMPACT) (F–NI)
Fire or smoke in or on the aircraft, in flight, or on the ground, which is not the result of impact.

SECTION 4 – SAFETY RECOMMENDATIONS

4.1. Safety Recommendations

4.1.1. Aircraft Operator

4.1.1.1. Review and revise the compressor wash interval policy to account for actual environmental operating conditions, including increased wash frequency or condition-based washing for aircraft operating in dusty or polluted routes.

4.1.2. Aircraft Manufacturer

4.1.2.1. Evaluate and, if necessary, update the environmental classification guidance and maintenance planning documentation to better support operators in tailoring maintenance intervals for harsh operational environments.

4.1.3. PCAA

4.1.3.1. Ensure environmental factor operational risks are adequately reflected in the aircraft's airworthiness and safety programs for all operators.