FINAL INVESTIGATION REPORT

SERIOUS INCIDENT OF M/S. PIAC FLIGHT PK-4522 (SECTOR SKD – ISB) ATR 42-500, AP-BHO ENGINE NO. 1 UNCOMMANDED SHUTDOWN ON 15TH SEPTEMBER, 2014 AT SKARDU

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Synopsis

The serious incident was reported to Safety Investigation Board (SIB) by the operator through Mandatory Occurrence Report (Appendix 'A') and was notified in accordance with ICAO Annex-13 by SIB (Appendix 'B'). The investigation was conducted by SIB Pakistan (the state of registry and occurrence). Director General of Pakistan Civil Aviation Authority (CAA), issued Memorandum vide letter No. HQCAA/1901/363/SIB/606 dated 18th September, 2014 (Appendix 'C'), authorizing SIB, Pakistan to investigate the serious incident.

The aircraft experienced a loud bang followed by Engine No.1 uncommanded shut down during climb out at approximately 14000 ft. The aircraft made a safe single engine landing at Skardu.

The most probable cause could be the accumulation of environmental contaminants through serviced oil or formation of burnt oil residues in the jets due to inadequate cooling prior to engine shut downs during service life of the engine. This led to the failure of bearing No. 2 of the engine after oil starvation due to blockage of its oil delivery jets.

1. FACTUAL INFORMATION

1.1 **History of the Flight**. The Pakistan International Airline Corporation (PIAC) ATR 42-500 aircraft, Registration No. AP-BHO was on routine passenger flight PK-4522 from Skardu to Islamabad on 15th September, 2014. After takeoff while climbing out through 14000 ft the crew heard a loud bang followed by uncommanded shut down of Engine No.1. Requisite checklist actions were taken and aircraft landed back at Skardu.

1.2 **Injuries to Persons**. None

1.3 **Damage to Aircraft**. None

1.4 **Other Damages**. None

1.5 **Personnel Information.** Not applicable

1.6 **Engine Information.**

Engines Make and Model	PW127E
Engine No.1 Serial Number	EB 0290
Engine No.1 Time since new (TSN) / Cycles since new (CSN)	14441 hrs / 14513 cycles
Engine No.1 Time since overhaul	6175 hrs / 6269 cycles
Last Shop visit (Hot Section Inspection)	7th April, 2014 13250 hrs TSN and 13255 CSN
Engine assigned life after last shop visit	19019 TSN / 18250 CSN

1.6.1 The aircraft was maintained in accordance with approved maintenance schedule and there was no outstanding defect which could contribute to the occurrence.

1.7 **Meteorological Information.** Not applicable

1.8 **Aids to Navigation.** Not applicable

1.9 **Communications.** Not applicable

1.10 **Aerodrome Information.** Not applicable

1.11 **Flight Recorders.** FDR data was downloaded and reviewed during the process of the investigation.

1.12 **Wreckage and Impact Information**. Not applicable.

1.13 **Medical and Pathological Information**. Not Applicable

1.14 **Fire**. Not Applicable

1.15 **Survival Aspects**. Not Applicable

1.16 **Test and Research**. Post occurrence tear down examination of the engine was conducted at PIAC shop. No. 2 bearing post failure analysis was performed at Institute of Space Technology (IST), Failure Analysis Centre (FAC), Pakistan.

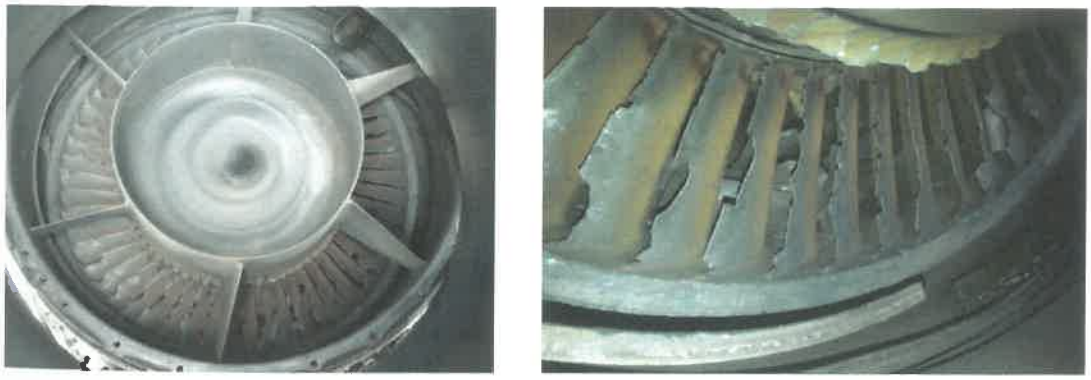
1.17 **Organisational and Management Information**. Not applicable

1.18 **Additional Information.** Not applicable.

1.19 **Useful or Effective Investigation Techniques**. Standard investigation procedure and techniques were used.

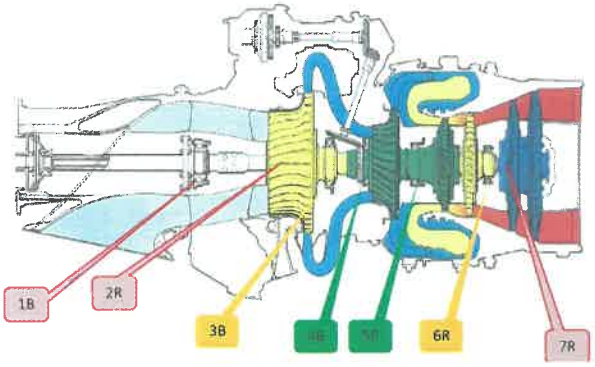
2. ANALYSIS

2.1 On wing inspection of the engine revealed damage to power turbine and free turbine. Post occurrence oil quantity was found within normal limits. The metal particles were found in metal chip detectors (MCD). Borescope inspection revealed severe internal damage to engine.



Power and free turbine damage, pictured on post flight

2.2 The following schematic shows relative position and numbers of PW127E bearings.



Engine schematic: (R and B stand for roller and ball bearing respectively)

2.3 Strip examination of the engine did not show evidence of foreign object damage in intake area and low pressure and high pressure compressors. Rubbing on the tips of the impeller supported the possibility of misalignment of shafts due to No. 2 bearing failure.

2.4 No. 2 roller bearing was found dry and in extensively damaged condition. Due to No. 2 bearing failure engine shafts got misaligned and apparently showed signs of exposure to extensive frictional / thermal stress (melting). The part of the Power Turbine (PT) shaft got melted away (approximately 20 cm) due to frictional/combustion heat and the molten material was observed spread over internal cavities. As depicted in the schematic diagram the No.2 bearing is not located in hot zone of the engine. The most probable reason of observed thermal damage and melting of the Power Turbine (PT) shaft and Low Pressure (LP) Compressor shaft was friction due to rubbing of the shafts as they got misaligned after the bearing failure.

2.5 All other bearings were found intact with evidence of availability of lubrication.

2.6 The two oil jets designed to provide lubrication of No. 2 bearing were found totally (100%) blocked. The oil pressure was applied in accordance with the procedure for checking oil jet flow pattern. During this procedure no oil flow was observed from the oil jets. The external surface of the oil jets was clear of any dust or dirt accumulation. Fine metal wire was passed through the oil jets in attempt to collect the debris blocking the jets. The debris could not be collected due to very small size. However, passing of wire cleared the jets and subsequent application of pressure gave solid jet of oil.

2.7 The turbine blades and stators were also observed extensively damaged.

2.8 Following pictures depict the extent of damage observed during strip examination.

Comparison of PT shaft and LP shaft damage with new parts

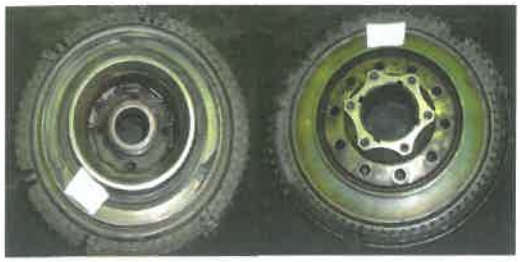
HP compressor and HP turbine and HP shaft damage

LP compressor

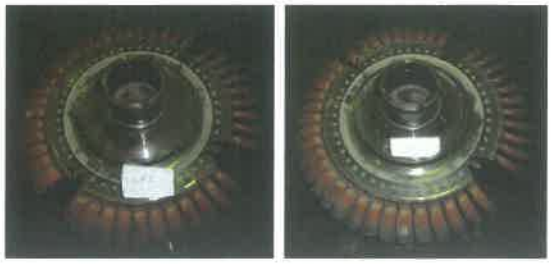
No. 2 Bearing and its housing

Internal view of No.2 bearing housing

No. 2 Bearing oil jets



Power turbine 1 and 2
(Blades removed for inspection)



LP and HP Turbine
(Blades removed for inspection)

2.9 The recovered portion of No. 2 roller bearing was dispatched to FAC for failure mode and fractographic analysis. The FAC report (Appendix 'D') conclusions are summarized below:

2.9.1 Oxide/metal deposits were found on half of the inner race, indicating that bearing had already been ceased when it got exposed to fire.

2.9.2 Cups of the bearing cage were deformed due to friction between the rollers and the inner race during dry run.

2.9.3 Rollers got melted and their remains were deposited on the inner race of the roller bearing as the bearing got exposed to tremendous heat.

2.9.4 Evidence of dry run on the inner race were found, which may have been result of low or no oil lubrication in the bearing.

2.10 It is pertinent to mention that No.1 and No.2 bearing have a common filter before the oil gets into the bearing cavity. The possibility of blockage of this filter due to contamination was ruled out as No.1 bearing was found intact and with evidence of lubrication.

2.11 On aircraft oil cannot directly be serviced into engine and needs a funnel. After this occurrence, based on engine manufacturer (P&W Canada) feedback, the operator has issued engineering instruction to ensure the cleanliness of funnel. The use of funnel always carries potential of inclusion of dust keeping in view the dusty environment of the airports where ATR fleet operates in Pakistan. The use of oil dispensers may provide better protection against environmental contaminants provided such equipment is approved by the manufacturer.

2.12 The operator had experienced similar problem of bearing No.2 oil jet blockage on PW127E Engine S. No. EB0284 (at 9544TSN / 8546 CSN) on 1st June, 2012. The reason on blockage could not be ascertained.

2.13 The operator's engineering instruction vide Circular-11/2016 dated 19th April 2016 is based on their interaction with the manufacturer to address PW127E engine problems which had been faced by PIAC in the past. The recommendations of the circular are reproduced below:

2.13.1 Always use a clean funnel for OIL replenishing and ensure that funnel is kept in polythene bag before placing it in box to keep it free from Dust/debris etc.

2.13.2 Visually inspect the funnel before OIL charging and do not clean with rag, if found dirty wash it thoroughly OR use another Clean Funnel.

2.13.3 Charging of OIL at transit check should be minimum and the OIL charging in Daily Check would be recommended.

2.13.4 Battery starting should be avoided or keep it to minimum.

2.13.5 For engine washing always use recommended water and keep record of issuing the water/solvent in Line Maintenance (Shiftwise).

2.13.6 Follow TSE Circular Number 11/2015 dated 25-05-2015 (available on PIA Web) for engine washing to avoid ingestion of dust / moisture in HMU.

2.13.7 Whenever Oil filter is found popped out, carry out relevant trouble shooting & must record the finding in ATLB and also inform the same to TSE-LM.

2.13.8 Running the Engine at Hotel mode should be kept minimum to save engine operating life as well as to avoid FOD.

2.13.9 An engine cool down period of two minutes at power lever angles below Flight Idle prior to shut down will assist hot section temperature equalization and lower hot section components metal temperature. It also reduces the residual heat build-up in the engine / nacelle and most importantly reduces the level of fuel nozzle coking.

2.13.10 Check the OIL within 30 minutes after engine shut down and 15(+/-) 5 minutes is considered optimum.

2.13.11 Experience has shown that OIL level kept at "ADD 1" mark provides satisfactory result from OIL consumption point of view.

2.14 Based on the available evidence and manufacturer's literature the exact reason of No.2 bearing oil jet blockage could not be established. One of the probable reasons could be introduction of small environmental contaminants which passed the system filters and accumulated over time in the oil jets. The second probable reason could be formation of coke or oil burn products in the oil jets similar to fuel nozzle coking due to inadequate cooling before engine shut down.

3. CONCLUSION

3.1 Findings

3.1.1 There was no evidence of in flight or on ground engine oil loss.

3.1.2 The oil jets meant for lubrication of No. 2 bearing were found completely blocked.

3.1.3 No. 2 bearing sustained frictional damage after it suffered oil starvation due to blocked lubricating oil jets.

3.1.4 After No. 2 bearing failure, the concentric shafts (PT shaft, LP shaft, Hp shaft) got misaligned and suffered extensive thermal damage due to rotational friction.

3.1.5 The rest of the engine damage was consequence of No. 2 bearing damage.

3.2 **Cause of Occurrence**

3.2.1 The cause of the occurrence was blocked lubricating oil jets of No. 2 bearing, subsequently the bearing got damaged due to dry running.

3.2.2 The exact reason of oil jets blockage could not be established, however most probable cause could be accumulation of environmental contaminants through serviced oil or formation of burnt oil residues in the jets due to inadequate cooling prior to engine shut downs during service life of the engine.

4. SAFETY RECOMMENDATIONS

4.1 Keeping in view the harsh weather environment, the operator (PIAC) to implement following recommendations to avoid similar occurrences in future:

4.1.1 To educate technical crew on best practices to ensure engine oil servicing free of environmental contamination.

4.1.2 Consider implementation of monitoring of FDR data for adherence to approved engine shut down and ground operation.

4.1.3 Consider use of suitable engine oil dispenser instead of funnel after getting due approval from the aircraft/engine manufacture.

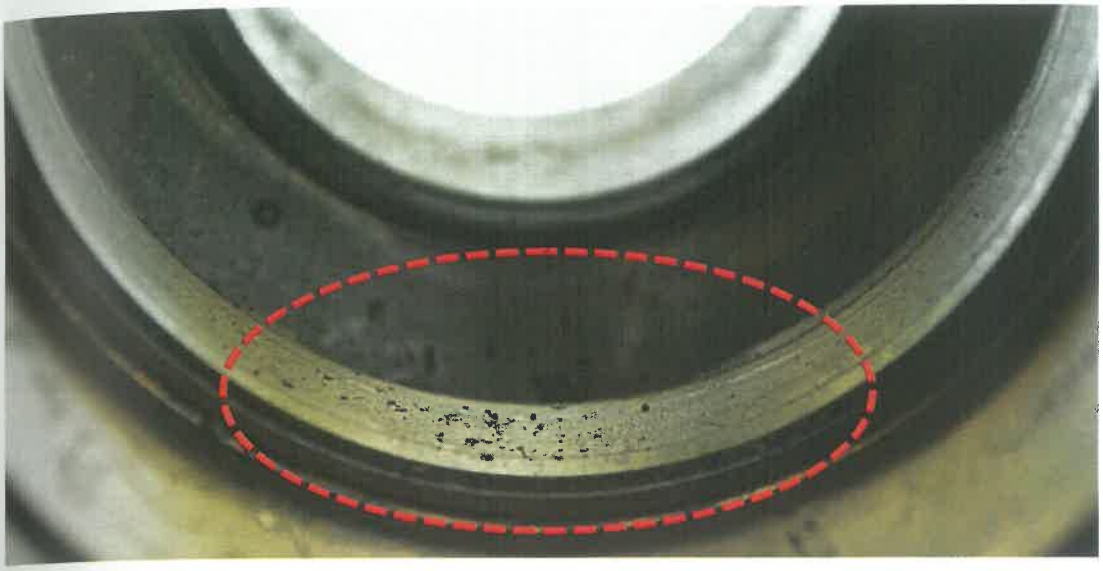


Fig. 5. Outer race of roller bearing exhbiting wear marks.

Fig. 6. Inner race of roller bearing attached with left over portion of PT shaft.

Fig.7. Oxide deposites on the inner race of roller bearing.

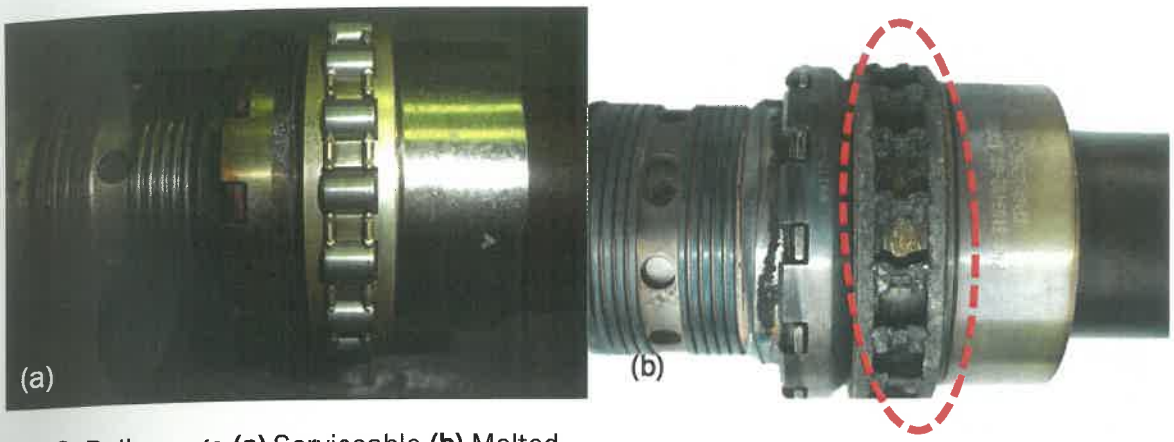


Fig. 8. Roller cage **(a)** Serviceable **(b)** Melted.

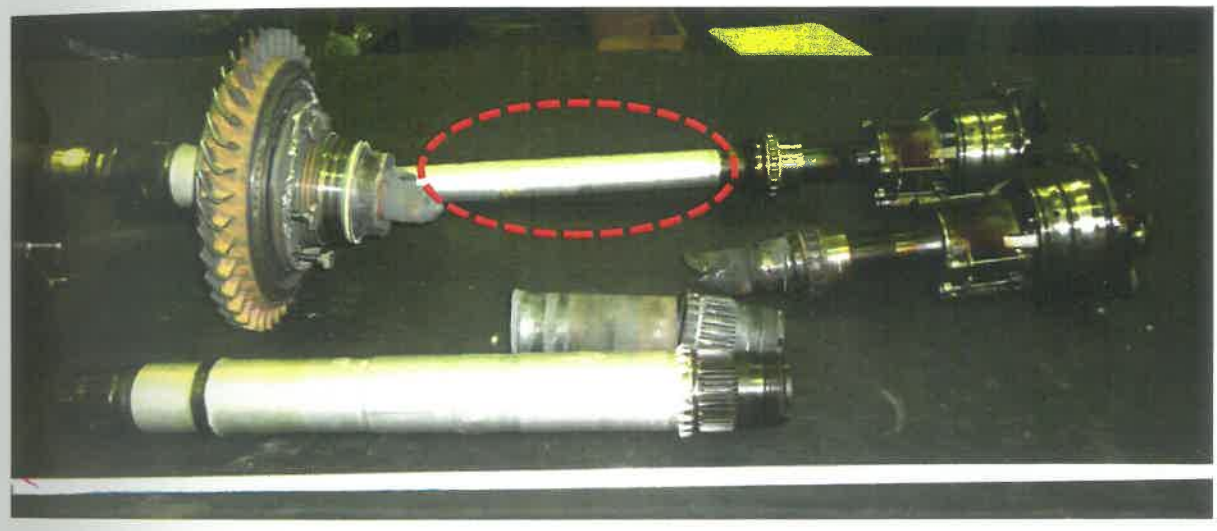


Fig. 9. Serviceable PT shaft and damaged PT shaft.

Fig. 10. Disassembled inner race of roller bearing.