پاکستان سول ایوی ایشن اتھارٹی

PAKISTAN CIVIL AVIATION AUTHORITY

(SAFETY INVESTIGATION BOARD)

FINAL REPORT

M/S PIAC BOEING 777-300 AIRCRAFT REG # AP-BHV (SECTOR ISB - LHR) EXPERIENCED UN-COMMANDED IN-FLIGHT ENGINE NO. 1 SHUTDOWN (IFSD) AND SAFELY LANDED AT SHEREMETYEVO AIRPORT, MOSCOW WITH SINGLE ENGINE OPERATION ON 21st JULY, 2013

(+) M/s GE Aviation has paid 1.43 million US Dollars as a result of this investigation to M/s PIAC for causing damage to their mishap GE90 engine. SA to PM Nawaz Sharif briefed on the subject.
17/06/2015
President SIB

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Dated: 17th June, 2015

INVESTIGATION INTO SERIOUS INCIDENT OF M/S PIAC FLIGHT PK-785, B-777-300ER AIRCRAFT, REG NO. AP-BHV, (SECTOR ISB – LHR) EXPERIENCED ENGINE NO 1 (GE90) UN-COMMANDED IN-FLIGHT SHUT DOWN (IFSD) WHILE CRUISING AT FL 360 ON 21ST JULY, 2013

1. Reference is made to the above mentioned serious incident.

2. An in-depth investigation and analyses of all available evidences relating to the said serious incident was carried out. The major findings of the investigation along with safety recommendations are appended in succeeding paragraphs.

3. **Findings**

3.1. M/s PIAC Boeing 777-300ER aircraft, Reg # AP-BHV, Flight PK-785 was on a scheduled passenger flight from Islamabad to London on 21st July, 2013.

3.2. The mishap aircraft was serviceable on the day of occurrence and properly serviced prior to the departure of scheduled flight.

3.3. There was no outstanding snag related to mishap engine.

3.4. There was no outstanding Service Bulletin or OEM defined inspection / maintenance task on mishap engine.

3.5. At 05:19 GMT, the aircraft took off from BBIAP, Islamabad.

3.6. At 07:09 GMT (after 1 hr and 50 minutes flight) Debris Monitoring System (DMS) abnormal chip count fault {(7914561 FAULT: DMS (Left Engine)} was generated on Engine Indicating and Crew Alerting System (EICAS). First Officer observed the status message and did not take any remedial action as no action by cockpit crew is defined in QRH, FCOM and Ops Manual.

3.7. At 09:20 GMT, the mishap aircraft experienced Engine No. 1 un-commanded in-flight shutdown (IFSD). The cockpit crew carried out the remedial corrective actions as per QRH, FCOM and Ops Manual. The nearest airport was Sheremetyevo, Moscow (300nm) and a safe single engine operation landing was made after 55 minutes.

3.8. At 07:09 GMT, the fault status message was communicated by Aircraft Communication Addressing and Reporting System (ACARS) to GE Aviation

Remote Diagnostics, USA and Customer Notification Report (CNR) was generated by GE at 11:22 GMT to the operator. The CNR was generated by the GE Aviation and received by the operator as per the existing procedure in vogue.

3.9. During the process of investigation, it was observed that CNR was communicated to the operator 4 hours and 13 minutes after the fault generation (practically after safe landing of mishap aircraft at Moscow) whereas; IFSD took place after 2 hrs 11 minutes of generation of chip count fault.

Strip Examination of Mishap Engine at M/s GE MRO Facility, Cardiff, UK

3.10. Mishap Engine was dis-assembled in the presence of President Safety Investigation Board CAA Pakistan at GE MRO facility at Cardiff Wales, UK while following the standard procedure of the MRO facility.

3.10.1. Boroscopic inspection (BSI) of High pressure Compressor (HPC) revealed liberated leading edge tip corner and nick on one of the No. 5 and No. 9 stage compressor blades respectively. This damage was, however within authorized re-workable limits defined by the OEM.

3.10.2. During disassembly one roller (deformed to hexagonal shape) and two pieces of inner race of Starter Drive Shaft Roller Bearing were found inside the Transfer Gear Box (TGB) end of Horizontal Drive Shaft (HDS) cover tube towards the TGB end.

3.10.3. Ultrasonic wall thickness measurement of HDS was carried out in accordance with Service Bulletin (SB) 72-0471 and it was found **out of allowable balance limits** at specified locations.

3.10.4. The unbalance was observed 938 g-mm against the acceptable limit of 450 g-mm.

3.10.5. The measurement at M/s Avio Aero, Italy also confirmed the unbalance findings of HDS.

3.10.6. Accessory Gear Box (AGB) was disassembled at Accessory Business Unit (ABU) of GE, Cardiff. Seventeen rollers (many deformed to hexagonal shape), two pieces of inner race and pieces of cage were recovered from AGB housing.

3.10.7. No visual anomaly was noted on remaining five main bearings of the mishap engine.

3.10.8. TGB and IGB were disassembled in presence of M/s Avio Aero, Italy engineer and no apparent damage was noted whereas AGB had the visible damage on gears. The AGB, TGB and Intermediate Gear Box (IGB) were dispatched to M/s Avio Aero, Italy for further examination and analysis.

3.10.9. During stripping the HDS) was removed and the exposure of the AGB confirmed that the Starter Drive Shaft forward roller bearing had disintegrated.

3.10.10. The contact damage and heat discoloration of starter gear shaft and gear teeth inside AGB was due to loss of axial position because of bearing failure and subsequent rubbing with AGB roller bearing outer race studs.

3.10.11. TGB bevel gear shafts had fretting wear and axial scratches on the operating surfaces.

3.10.12. The M45 Combustor Module inner liner had two cracks running axially from the inner lip, adjacent to deflector plates No. 3 and No.7. A third crack was noted adjacent to deflector plate No. 22, with loss of material from the inner liner. The outer deflectors were in a poor condition with loss of material, at locations No. 6, 18, 20 and 26.

3.10.13. All nozzles of M55 High Pressure Turbine (HPT) S1 Nozzle Module featured concave gas path surface distress, either to the leading edge airfoils or to the inner platform, with cracking and peeling back of material and 11 nozzles were observed having brazed joint cracking.

3.10.14. Several nozzles of M56 HPT S2 Nozzle Module had thermal distress with open cracking and loss of material. The nozzles at location No. 3 and 5 exhibited significant distress.

3.10.15. The pre Service Bulletin 72-0348 HPT Stage 1 Shrouds, Part Number 1847M52P10, featured erosion and cracking, without any holes in the gas path surface.

3.10.16. The HPT Stage 1 Blades, Part Number 2084M61P06, had significant TBC loss, leading edge erosion and tip cracking. Four blades had large leading edge impact damage dents and 42 blades of HPT Stage 2, Part Number 2084M51P04 suffered leading edge damages.

3.10.17. The Turbine Rear Frame (M63 Module) had three cracks up to 0.5 inches long to the rear mount lug inner location.

Lab Analyses

3.11. Lab analyses using Scan Electron Microscope (SEM) and Metallographic equipment revealed following significant observations:

3.11.1. Wear / fretting indications were visible on outer diameter (OD) of the Outer Ring (OR). The dents were observed on the OD edge. OR race had “moved towards one side” along with spalling and non spalled surface observed worn out. The spalling and smearing was observed on both upper and lower part of the race.

3.11.2. The outer diameter of the Inner Race (IR) was found smeared along with worn out condition. Its shoulders had plastic deformation with multiple dents. The fractured surface SEM evaluation revealed plastic deformation and smear / distress. The spalling parallel to the surface indicated progression of failure. Metallography evaluation of IR did not reveal any evidence of discrepancies in microstructure.

3.11.3. The load calculations with HDS unbalance, L10 factored life calculations and IR contact pressure calculations at Equivalent Speed (12023 RPM-average conditions during operation) and takeoff speed (13776 RPM) were carried out at OEM Facility. The calculations were observed in agreement with the lab observations on damaged bearing debris / parts.

3.11.4. It was observed that at equivalent speed, the calculated L10 factored bearing life with discovered unbalance is reduced by 95% as compared to bearing life with balanced HDS.

3.11.5. The investigation revealed that radial load on rollers with the present unbalanced HDS was observed increasing by about 2.5 times the load encountered in normal operation with balanced HDS.

3.11.6. The roller contact pressure profile calculations showed high stress at roller edges at takeoff speeds which was supported by the evidence of spalling on outer ring of the bearing.

3.11.7. The rotating un-balanced HDS shaft caused a rotating or cyclic load and thus fatigue of the IR. In the region of application of this dynamic load, the radial clearances reduced and on the opposite side the clearances increased. This cyclic displacement of OR inside the Aluminium housing resulted in fretting on outer diameter of the OR and its studs. This also contributed to misalignment of the rotating shaft which further explains the observed spalling.

3.12. Strip examination of engine, AGB, TGB, and IGB along with Lab analyses of Debris revealed that starter roller bearing IR failed due to heavy cyclic loads caused by unbalance of the HDS.

3.13. The HDS un-balance was caused due to manufacturing non conformance at OEM Facility.

4. Summary of the Factors Leading to Serious Incident

4.1. The unbalance of the HDS produced higher than normal operating and cyclic loads on the starter roller bearing which resulted into its fatigue.

4.2. These loads caused spalling of race ways and roller slipping and ultimately breakage of IR and bearing cage.

4.3. The misalignment of HDS due to starter roller bearing failure coupled with rotation aggravated the operational conditions and starter ball bearing got unseated from its original position. Resultantly, the starter gear shaft contacted starter bearing studs and mating gears end faces which caused the secondary damages.

4.4. The damage and debris inside the AGB restricted rotation and ultimately resulted into the occurrence.

5. Cause of Occurrence

5.1. The cause of IFSD is starter roller bearing inner race failure. The IR failed because of high radial loads (cyclic) due to unbalanced HDS. The unbalance of HDS was caused as a result of manufacturing non-conformance at OEM level.

6. Safety Recommendations

6.1. M/s GE Aviation is to review the entire manufacturing process of HDS.

(The manufacturing process has been changed by M/s GE Aviation by instituting and incorporating balance and wall thickness checks as part of the manufacturing process).

6.2. M/s GE Aviation is to issue necessary instructions to all operators around the globe to avoid similar occurrence on GE90 engines.

(To address the problem of affected HDS population, M/s GE Aviation issued two SBs {SB 72-0478 (Category 2) and SB 72-0471 (Category 3)} for compliance and conformance by the operators and MRO facilities.

6.3. M/s GE Aviation is to issue instructions for one time ultrasonic inspection of remaining HDS on the GE90 engine fleet.

(M/s GE Aviation has issued instructions to accelerate the ultrasonic inspection for remaining HDS which had yet not been inspected in fleet).

7. Forwarded for your information and further necessary action, please.

To,

- **Director Safety Management**
  M/s PIAC JIAP, Karachi

Copy to:

Internal

- PSO to DG CAA
- Secy to Dy DG CAA
- PD (Reg) HQ CAA
- DAW HQ CAA
- DFS HQ CAA

External

- Joint Secretary Aviation Division, Cabinet Secretariat, Islamabad
- SO to Managing Director M/s PIAC JIAP Karachi
- Mr Scarfo Jean-Pierre (Accredited Representative NTSB, USA)