FINAL INVESTIGATION REPORT

SERIOUS INCIDENT OF SHAHEEN AIR INTERNATIONAL FLIGHT NL-122, B737-400, REG# AP-BJT EXPERIENCED ENGINE NO. 1 ANOMALY ON 21ST APRIL, 2015 AT BBIAP, ISLAMABAD

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Synopsis

The serious incident was reported to Safety Investigation Board (SIB) by the operator through Mandatory Occurrence Report (MOR) **(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). Deputy Director General of Pakistan Civil Aviation Authority (PCAA), issued Memorandum vide letter no. HQCAA/1901/368/SIB/292 dated 22nd April, 2015 **(Appendix 'C')**, authorizing SIB, Pakistan to conduct investigation as per ICAO Annex-13.

After takeoff from Islamabad, the aircraft experienced a loud bang followed by Engine No.1 high EGT, burning smell and vibrations. The affected engine was switched off and safe single engine landing was made at Islamabad.

The occurrence took place due to extensive damage to blades of High Pressure Compressor, High Pressure Turbine and Low Pressure Turbine. Most probably some damage / deterioration existed before the incident and could not be discovered during rectification of previously reported high Exhaust Gas Temperature (EGT) defects. This damage / deterioration aggravated over the time and resulted into the reported incident.

1. FACTUAL INFORMATION

1.1 **History of the Flight**. The Shaheen Air International (SAI) B737-400 Registration No. AP-BJT was on routine passenger Flight NL-122 from Islamabad to Karachi. After takeoff, at approximately 0537 (UTC), while passing through 3200 ft the crew heard a loud bang / thud followed by Engine No.1 high EGT (Red Light ON). The crew also reported vibrations and burning smell. Smoke trail from engine was reported by Air Traffic Services before landing. The affected engine was switched off and safe single engine landing was made at Islamabad. After landing fire services reported smoke from engine No. 1 exhaust but no external fire was observed.

1.2 **Injuries to Persons**. No injury to any crew member or passenger occurred as a result of this occurrence

1.3 **Damage to Aircraft**. There was no damage to the aircraft, except the internal damage to engine.

1.4 **Other Damages**. None

1.5 **Personnel Information.** Not applicable

1.6 **Aircraft and Engine Information.**

1.6.1 **Aircraft Information.**

Aircraft Make and Model	Boeing 737-400
Aircraft manufacturer's S No.	25740
Aircraft C of A Regular Air Transport, Charter Operations and Aerial Work Operation (Flying Training Only) category	Valid till 31st May, 2014
Aircraft Hours Since New (HSN) / Cycles Since New (CSN)	51826 hrs / 32867 cycles

1.6.2 **Engine No. 1 Information**

Make / Model	GE / CFM56-3C-1
Serial Number	856675
TSN / CSN	47379 hrs / 30275 cycles
Installation date on AP-BJT	13th Feb, 2013
Last Inspection	Check A-1 at Karachi on 8th April, 2015
Last Borescope Inspection (BSI)	At Karachi during Check A-4 on 3rd December, 2014

1.6.3 The aircraft used Jet A-1 fuel.

1.6.4 The aircraft was maintained in accordance with approved maintenance schedule. The last six months defect history of the aircraft was reviewed. The documented defects / maintenance in tech log book **(Appendix 'D')** which could possibly relate to the observed anomaly are listed below:

Date and Defect	Rectification
20th March, 2015: After selection of climb thrust Engine #1 EGT was 910°C, adjusted manually.	Engine #1 inlet and exhaust area visually checked, found no abnormality. Reset PMC #1, also examined CIT and T2 sensor IAW AMM 71-00-42 Fig 104.
30th March, 2015: During climb up to FL100, EGT tends to exceed maximum. N1 reduced by 5% to keep EGT within limit.	Inlet and Exhaust inspection carried out as per AMM 71-00-00. Ground run carried out All parameter checked, found satisfactory.
18th April, 2015: After takeoff Engine #1 EGT went to 935°C for one second.	Engine #1 inspection c/out IAW AMM 71-00-00/601, found 935°C fall in area 'A', 930°C & 940°C which is allowed for less than 20 sec, please observe further.
20th April, 2015 (At Multan): During post flight inspection, bird feathers found inside left engine and right wing root.	Ground runs carried out by Captain all parameters checked, found SAT. Detail inspection carried out regarding bird strike as per AMM task 05-51-37-212-001, no abnormality found.
20th April, 2015 (After aircraft return to Karachi): Ref Seq#063 Engine #1 Bird Strike.	Engine #1 inspection carried out for engine post FOD / bird strike, checked found sat. Bird ingestion cleaning carried out IAW 71-00-58/125 and 72-00-00/709 respectively.

1.6.5 The aircraft flew two flights after the bird strike and before the mishap flight without any documented reported defect.

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**. There was no evidence of in-flight or post occurrence fire.

1.15 **Survival Aspects**. Not Applicable.

1.16 **Test and Research**. Not Applicable.

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 The analysis of defect history rectification and referred Aircraft Maintenance Manual (AMM) task cards was performed and following observation were noted:

2.1.1

30th March, 2015: During climb up to FL100, EGT tends to exceed maximum. N1 reduced by 5% to keep EGT within limit.	Inlet and Exhaust inspection carried out as per AMM 71-00-00. Ground run carried out All parameter checked, found satisfactory.
Observation: AMM 71-00-00 does not address high EGT problem, rather it deals with different engine inspections. With the High EGT defect on 20th March, 2015 in background the application of high EGT checks AMM 71-00-42 **(Appendix 'E')** was more appropriate.	

2.1.2

18th April, 2015: After takeoff Engine #1 EGT went to 935°C for one second.	Engine #1 inspection carried out IAW AMM 71-00-00/601, found 935°C fall in area 'A', 930°C & 940°C which is allowed for less than 20 sec, please observe further.
Observation: AMM 71-00-00/601 **(Appendix 'E')** is the first page of Power Plant Inspection / check procedure. The complete procedure deals with power plant inspection and power plant (smoke / fumes in cabin) inspection. More appropriate reference could have been AMM 71-00-00/230 **(Appendix 'E')** which defines over temperature limits.	

2.1.3

20th April, 2015 (At Multan): During post flight inspection, bird feathers found inside left engine and right wing root.	Ground runs carried out by Captain all parameters checked, found SAT. Detail inspection carried out regarding bird strike as per AMM task 05-51-37-212-001, no abnormality found.
Observation: AMM 05-51-37-212-001 deals with Bird / Hail Strike Conditional Inspection of aircraft. This task card makes reference to Foreign Object Damage (FOD) Inspection (AMM 72-00-00-206-059-C00) which further refers Bird Strike or FOD with Normal Parameters checks (AMM Figure 102/71-00-47-990-802-C00). This procedure asks for BSI if debris appear to have entered into gas generator or missing material on fan blades is discovered. The rectification ground run was carried out by the Captain of the aircraft; and aircraft had a routine flight to back to Karachi. Subsequently inspection in accordance with AMM 71-00-58/125 and cleaning in accordance with AMM 72-00-00/709 was performed at Karachi. The documented rectification did not indicate any requirement of BSI.	

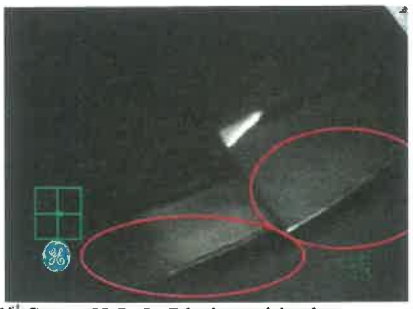
2.2 From the above analysis it can be noted that some of the documented AMM task card reference numbers were not exactly applicable for the situation. Such documentation anomaly indicates more reliance on memory rather than actual consultation of task cards during maintenance.

2.3 The analysis of the documented rectifications performed for High EGT problem indicated that no abnormality was discovered during rectification process. In accordance with trouble shooting diagrams in AMM 71-00-42 **(Appendix 'E')** the logical sequence in case of no discovered abnormality ends up at Borescope Inspection (BSI); however the same was not performed. Prior to the occurrence BSI of hot section of the engine was performed on 3rd Dec, 2014 during A-4 check and no abnormality was discovered during this inspection.

2.4 After the mishap flight, BSI **(Appendix 'F')** of the affected engine was performed. The significant findings are presented and analyzed in following sub paragraphs:

2.4.1 During inspection fan blades were found shingled, which were adjusted and further inspection was performed. The fan blades were found hard to rotate. There was no significant damage to Inlet section, Fan blades and Low Pressure Compressor (LPC). The leading edge erosion and environmental build ups were found but they were permissible in accordance with applicable publications and therefore, LP section inspection was declared satisfactory. The possibility of engine damage due to bird strike was therefore, ruled out.

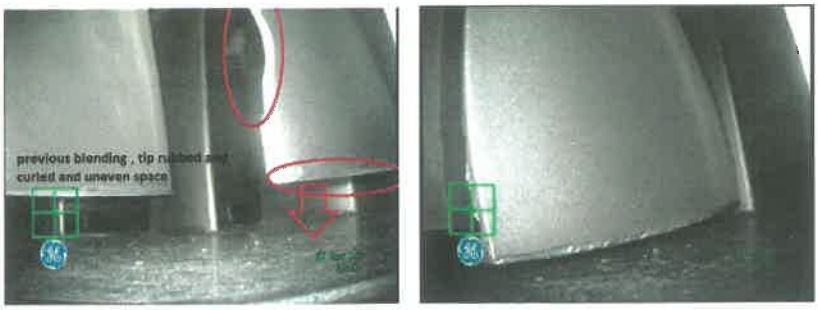
2.4.2 High Pressure Compressor (HPC) blades had heavy tip rubbing on almost 80% of the blades in all stages. Leading edge erosion was noted on maximum blades and some blades had tip curled but were not found in contact with stationary part. Uneven tip clearances were found on almost all stages blades. The erosion coating was intact on all blades. The leading edge erosion may possibly be a cumulative effect over time. The curling and bends on the tip of the blades without being in contact with stationary parts possibly indicated cumulative effects over period of time and aggravation due to compressor stall/severe airflow disturbance in the mishap flight.



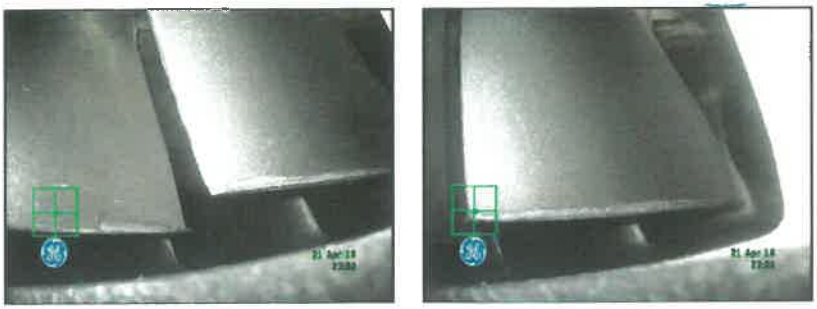
1st Stage H.P.C. Blades with clappers With tip rubbed

1st Stage H.P.C. Blades with clappers without tip rubbing

2nd Stage H.P.C. Blade with rubbing from tip and tip curled as well



6th Stage H.P.C. Blade with uneven clearance and tip erosion

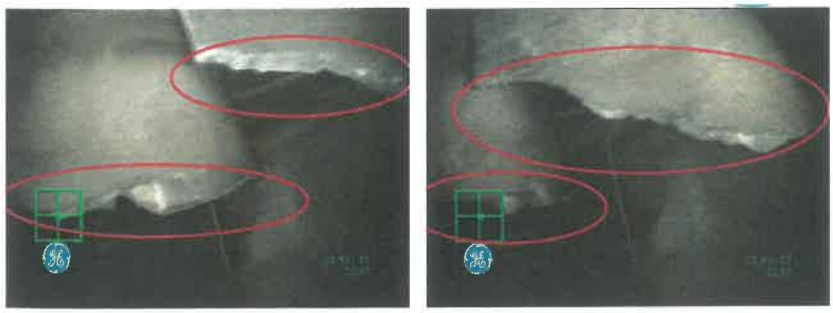


9th Stage H.P.C. Blade with uneven clearance and tip rubbing

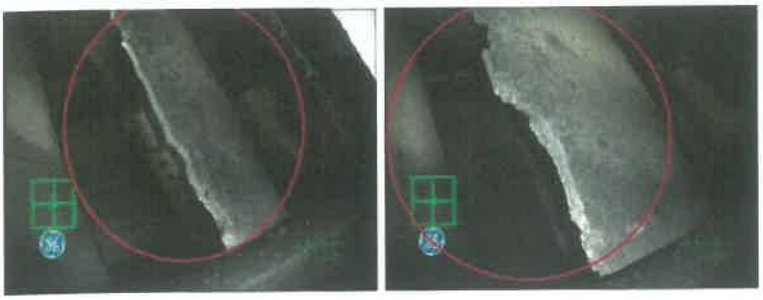
2.4.3 Combustor and fuel nozzles were declared satisfactory in accordance with applicable publications.

2.4.4 High pressure (HP) Nozzle Guide Vanes (NGV) had heavy carbon deposits and discoloration was also noted at different locations. The condition remained undetermined due to carbon deposits.

2.4.5 On trailing edge of HP turbine blades material was found missing from area "A", "B" and extending to area "C". More than 50% of blade material was missing on 09 blades. Discoloration was noted at different locations with carbon deposits on the surface and CODEP coating material was found missing. The condition was declared unsatisfactory based on applicable publications.

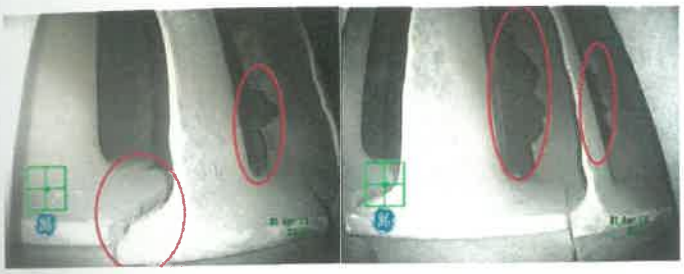


More than 50% of blade is missing extending to area C, which is found on 09 blades



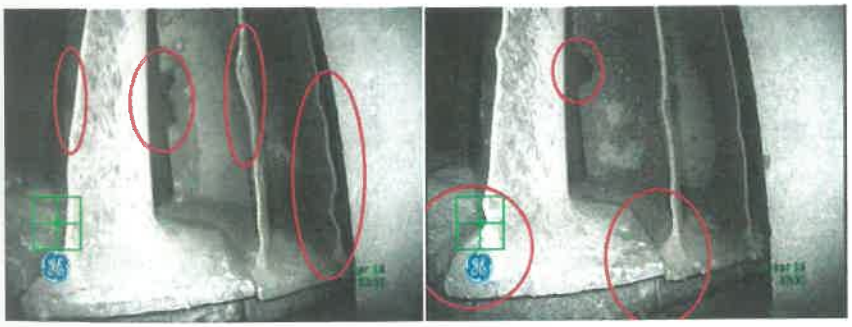
Material missing/ burn from leading edge extending to area C on T/E

2.4.6 Low Pressure Turbine (LPT) all stages' blades had missing material, nicks, tip shrouds overlap and unlatched. Discoloration and coating loss were also observed. The condition was declared unsatisfactory in accordance with applicable publications.

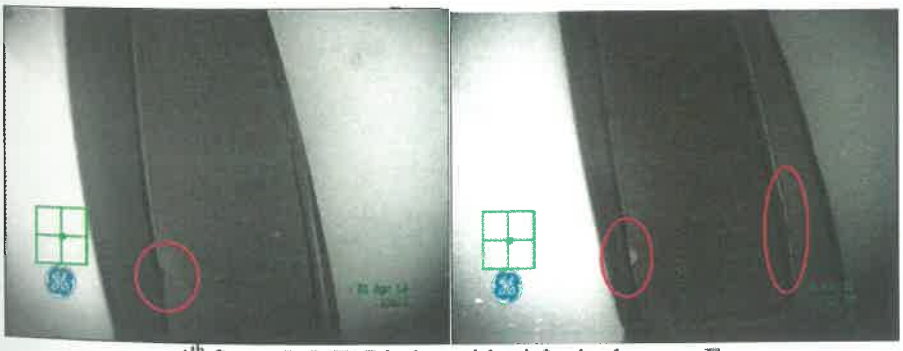


1st Stage L.P.T. Blades with nicks, metal missing, distortion

1st Stage NGVs



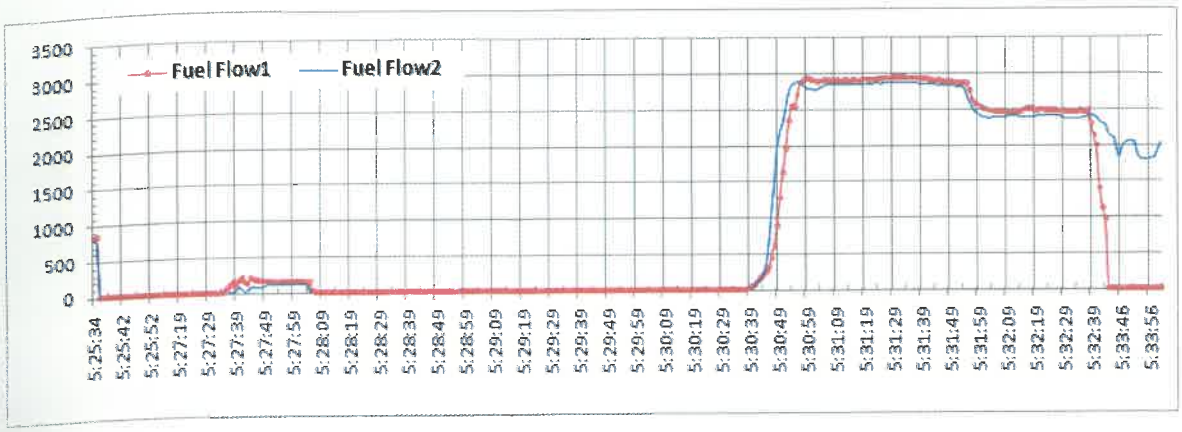
2nd Stage L.P.T. Blades with nicks, metal missing, distortion and tip shroud overlap

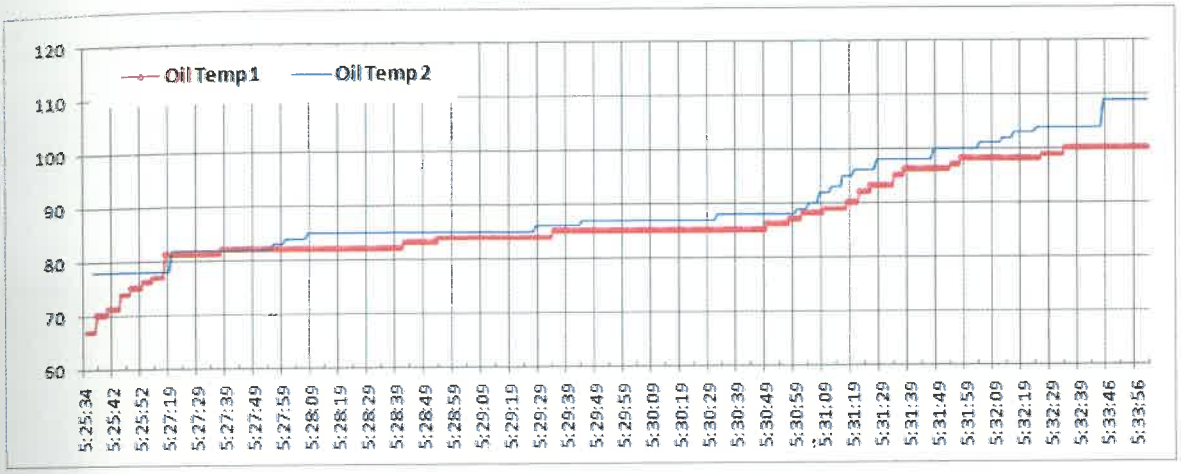


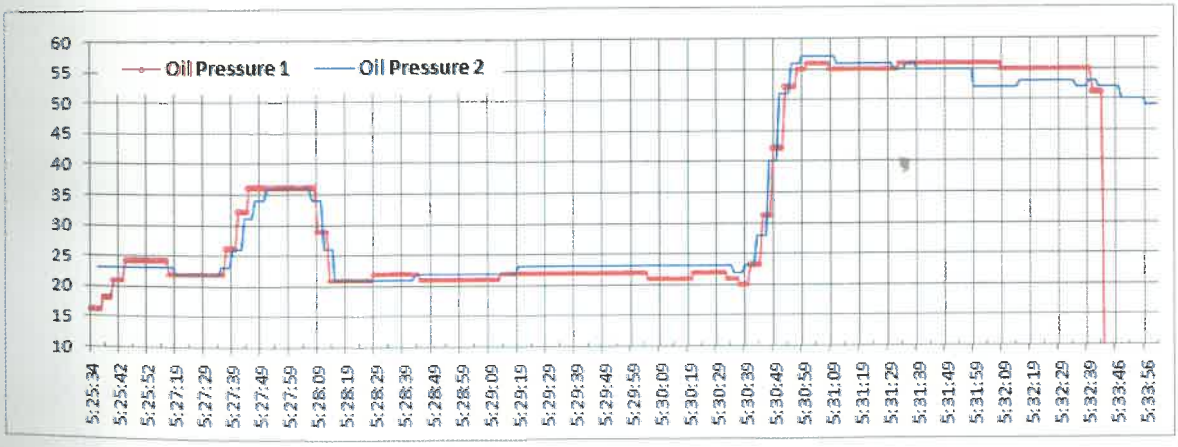
4th Stage L.P.T. Blades with nicks in the area E

2.5 The plots of relevant FDR parameters vs FDR time from start of the flight till shut down of the affected engine are presented below :

Engine Parameters FDR Plots-1 Vs FDR Time







Engine Parameters FDR Plots-2 Vs FDR Time

Engine Parameters FDR Plots-3 Vs FDR Time

2.6 The FDR data plots indicate that Engine No.1 EGT was higher than Engine No.2 at maximum throttle angle setting and it continued with the same trend till it peaked to 980°C at 5:32:42 FDR time and then throttle was retarded. During Engine No. 1 EGT rise time the throttle angle of the Engine No.1 was slightly lower than Engine No.2 which indicated that crew tried to control the rising EGT by retarding throttle. The fuel flow of Engine No.1 followed the throttle angle setting but its value remained slightly higher than respective value of other engine.

2.7 The oil temperature of Engine No.1 remained lower than Engine No. 2. Similarly oil pressure did not show significant variation, indicating that there was no engine oil system anomaly which led to higher than normal EGT.

2.8 In the middle of EGT rise period, vibrations peaks of HPC, LPT and HPT of Engine No.1 were recorded at FDR time 5:31:25, 5:31:29 and 5:31:33 respectively. Based on recorded vibration parameter, the component which experienced the problem first could not be isolated with certainty as the time of recorded parameter depends upon its sampling time / rate. However, the recorded parameter indicated an increase of vibrations of HPC, LPT and HPT during the EGT rise period. The absence of oil and fuel system anomaly and vibration parameter suggested performance anomaly initiated in either of HPC, LPT or HPT. The vibration parameters and BSI report supported the fact that HPC was the first component which experienced performance anomaly.

2.9 The maintenance record showed that no concrete cause could be determined and BSI was not performed while addressing the documented high EGT defects in the last one month. This leaves a strong possibility of some internal damage / deterioration which aggravated over time.

2.10 The tear down examination of the engine could not be performed due to prolonged delay by the operator in planning and arranging for the appropriate facility. In order to avoid further delay best possible effort was made to finalize the case on available evidence.

2.11 The very rapid EGT rise, loud thud, smoke trail and smell in the cabin suggested that HPC experienced stall first, while the damage of turbines blades was consequence of compressor stall. The possibility of existence of some internal damage / deterioration of profile of HPC blades could not be ruled out keeping in perspective the history of high EGT defects after takeoff with no concrete finding and absence of BSI. The analysis of available evidence suggests that HPC stall in the mishap flight occurred most probably due to pre existing damage / deteriorated condition of the HPC blades.

3. CONCLUSION

3.1 Findings

3.1.1 The aircraft was serviced properly before the flight.

3.1.2 During the last one month aircraft had three documented events of high EGT with no specific findings. The BSI was not carried out to determine the internal condition of the engine.

3.1.3 The aircraft experienced bird strike in Engine No.1 on 20th April, 2015 at Multan. The documented rectification indicated no damage to engine which implied no requirement of BSI. The rectification ground run was carried out by the Captain of the aircraft. Subsequently aircraft had a routine flight to Karachi. At Karachi engine was again inspected and post bird ingestion inspection and cleaning was performed.

3.1.4 The aircraft flew two flights after the bird strike and had no documented Engine No. 1 defect. The high EGT incident was experienced on third flight after the bird strike.

3.1.5 The post incident BSI discovered extensive damage to HPC, HPT and LPT.

3.1.6 The very rapid EGT rise, loud thud, smoke trail and smell in the cabin suggested that most probably HPC experienced stall first, while the damage of turbines blades was consequence of compressor stall.

3.1.7 The analysis of available evidence suggests that HPC stall in the mishap flight occurred most probably due to some damage / deterioration which existed before the incident and could not be discovered during rectification of previously reported high EGT defects. This damage / deterioration aggravated over the time and resulted into the reported incident.

3.1.8 While reviewing maintenance history and defect record it was found that some of the documented AMM task card reference numbers were not exactly applicable for the situation. The observed errors in documenting the applicable AMM task cards numbers were

indicative of more reliance on memory rather than actual consultation of the applicable task cards during maintenance.

3.1.9 The operator's Engine Health Monitoring programme at the time of the incident was found less effective in timely dissemination of engine health trends along with recommended maintenance actions to concerned maintenance staff.

3.2 **Cause of Occurrence**

3.2.1 The occurrence took place due to extensive damage to blades of High Pressure Compressor, High Pressure Turbine and Low Pressure Turbine.

3.2.2 Most probably some damage / deterioration existed before the incident and could not be discovered during rectification of previously reported high EGT defects. This damage/deterioration aggravated over the time and resulted into the reported incident.

4. SAFETY RECOMMENDATIONS

4.1 The Shaheen Air International (SAI) and Shaheen Engineering and Aircraft Maintenance Services (SEAMS) to educate the technical crew on importance of BSI inspection in case of high EGT defects which do not have any other apparent reason.

4.2 SAI and SEAMS to educate the technical crew on importance of analyzing history of previously reported similar defects in the same area during rectifications / maintenance.

4.3 In order to make the job of analyzing history of previously reported similar defects easier, the possibility of introducing Defect History Sheet with Technical Log may be considered by SAI and implemented after necessary approval from the Regulatory.

4.4 SAI and SEAMS to educate the technical crew on importance of correct identification and consultation of applicable AMM task cards, and risks involved in reliance on memory only during maintenance.

4.5 SAI and SEAMS to strengthen Maintenance Reviews and Quality Assurance measures to ensure correct documentation of referenced AMM task cards.

4.6 SAI and SEAMS to take measures to enhance effectiveness of Engine Health Monitoring programmes like SOAP and / or Critical Engine Parameters Monitoring and Analysis using post flight FDR data. The graphical records (Monitored parameters vs. Time plots) should be preferred so that trends can be identified easily. The programme is to concentrate on timely dissemination of trends and recommended maintenance actions to all concerned before the trends can grow into incidents.