FINAL INVESTIGATION REPORT

ACCIDENT OF M/S PIAC FLIGHT PK-259 (SECTOR SKT- MCT) B737-300, AP-BEH AT MUSCAT ON 11TH FEBRUARY, 2013

FINAL REPORT

ACCIDENT OF M/S PIAC FLIGHT PK-259 (SECTOR SKT- MCT) B737-300, AP-BEH AT MUSCAT ON 11TH FEBRUARY, 2013

Synopsis

The accident was notified by Public Authority of Civil Aviation (PACA) of Sultanate of Oman, Muscat **(Appendix 'A')** and through Mandatory Occurrence Report (MOR) by the operator **(Appendix 'B')**. The investigation was delegated to Safety Investigation Board (SIB), Pakistan (state of registry) by PACA, Oman and a memorandum was signed by the representatives of Civil Aviation Authorities of the both the countries **(Appendix 'C')**. Accredited Representatives (Accrep) were appointed by the state of occurrence (Sultanate of Oman) and the state of design, United States of America (USA). Director General of Pakistan Civil Aviation Authority (CAA), issued Memorandum vide letter No. HQCAA/1901/356/SIB/184 dated 19 March, 2013 and corrigendum vide HQCAA/1901/356/SIB/381 dated 23rd June, 2016 **(Appendix 'D')** authorizing SIB, CAA Pakistan to investigate the accident.

During landing the left main landing gear of the aircraft collapsed. The cause of the occurrence was shimmy of left main landing gear due to excessive play in the associated linkages.

1. FACTUAL INFORMATION

1.1. **History of the flight.** M/s PIAC Flight PK-259, Boeing 737-300 aircraft Registration No. AP-BEH was operating a routine revenue flight from Sialkot to Muscat on 11th February, 2013. The flight remained uneventful till landing. During landing at Muscat at 0930 UTC (daylight conditions), the left main landing gear of the aircraft collapsed.

1.2. **Injuries to persons.** There were no injuries to the any person onboard.

1.3. **Damage to aircraft.** The aircraft left wing sustained substantial damage around landing gear attachment points due to landing gear collapse. The shimmy damper piston and torsion link also fractured. The left engine cowling came in contact with ground and dragged along on the runway resulting in damage to engine cowling, lower engine parts, thrust reverser blocker doors and honey comb structure.

1.4. **Other damage.** There was no other damage reported as the result of this accident.

1.5. **Personnel Information**

(a) **Captain**

- Date of Birth : 25-01-1958
- ATPL No. : 1086 (A)
- Medical validity Date : Class One , valid till 30-5-2013
- Total Flying Experience : 12239.00 hrs
- CRM Refresher Validity : 18-10-2013

(b) **First Officer**

- Date of Birth : 10-01-1974
- CPL No. : 2224 (A)
- Medical validity Date : Class One, valid till 30-9-2013
- Total Flying Experience : 1924 hrs
- CRM Refresher Validity : 21-5-2014

1.6. **Aircraft information.** The mishap aircraft was maintained by the operator in accordance with the regulations of CAA, Pakistan. Transit check of the aircraft was carried out at Sialkot on 11th February, 2013. There was no carried forward defect related to the main landing gears. The mass and center of gravity of the aircraft were within prescribed limits.

1.6.1 **Aircraft**

- Aircraft Make & Model : Boeing 737-300
- Serial No. : 25504
- Year Manufacture : 1992
- Registration Marking : AP-BEH
- Total Aircraft Hours : 35312:41
- Total Cycles : 26383
- Total Landings : 26587
- Last Check-C : On 30th December, 2012
- Last Check-A : On 24th Jan, 2013 / 35264 hrs

1.6.2 **Left Main Landing Gear**

- Time Since New (TSN) : 57442 hrs
- Time Since Overhaul (TSO) : 15945
- Overhaul due landings/Date : 5055 / 8th June, 2015

1.6.3 **Right Main Landing Gear**

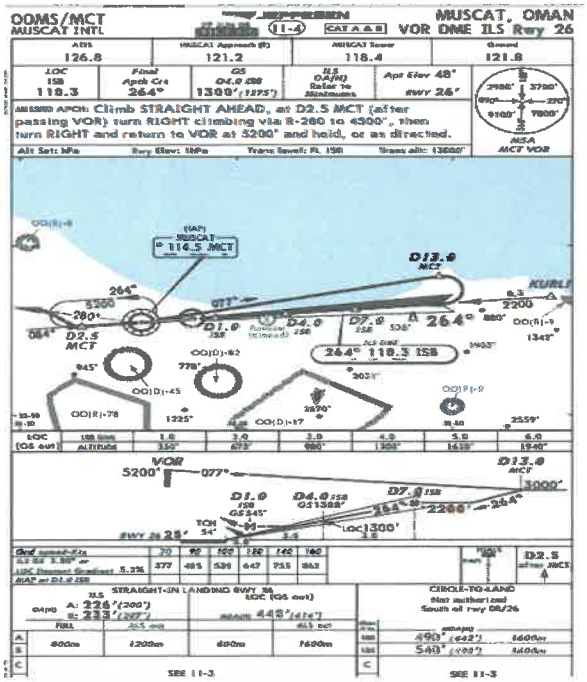
- Time Since New (TSN) : 40103 hrs
- Time Since Overhaul (TSO) : 15945
- Overhaul due landings/Date : 5055 / 8th June, 2015

1.7. **Meteorological information.** Not Applicable

Aids to Navigation. All required navigation aids whether onboard or at the landing airport were available and serviceable.

1.8. **Aids to Communications**. All required communication aids at the landing airport as well as onboard mishap aircraft were serviceable.

1.9. **Aerodrome Information.** The relevant Jeppesen chart for landing at runway 26 of Oman, Muscat is appended below:-



1.10. **Flight Recorders**. Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) were intact. The data from the units was successfully retrieved and utilized for the purpose of the investigation.

1.11. **Wreckage and Impact Information**. The SIB investigation team was able to visit the mishap aircraft, two weeks after the occurrence, on 27th February, 2013. The initial photographic evidence was preserved by PACA and broken hardware items were preserved. The aircraft remained intact after the collapse of the Left Main Landing Gear (LMLG). The left engine came in contact with the ground and dragged on the runway surface after collapse of the landing gear. The engine thrust reverser was in deployed position. The broken shimmy damper actuator was located in the vicinity of early stages of landing run before the aircraft final stopping point.

Aircraft on runway after final stop

Close up of the collapsed left main landing gear

1.12. **Fire**. There was no apparent evidence of fire. The flight crew reported that as the fire warning for the left engine came ON, they operated the fire extinguisher. After the aircraft came to a stop the foam was applied by Muscat fire Brigade.

1.13. **Survival Aspects**. After the accident the chutes were not deployed and passengers were disembarked using steps. No injuries to passengers and crew were reported.

1.14. **Tests and Research.** The visual examination and fractographic analysis of selected components of the mishap landing gear was performed and no material deficiencies or signs of fatigue failure were detected.

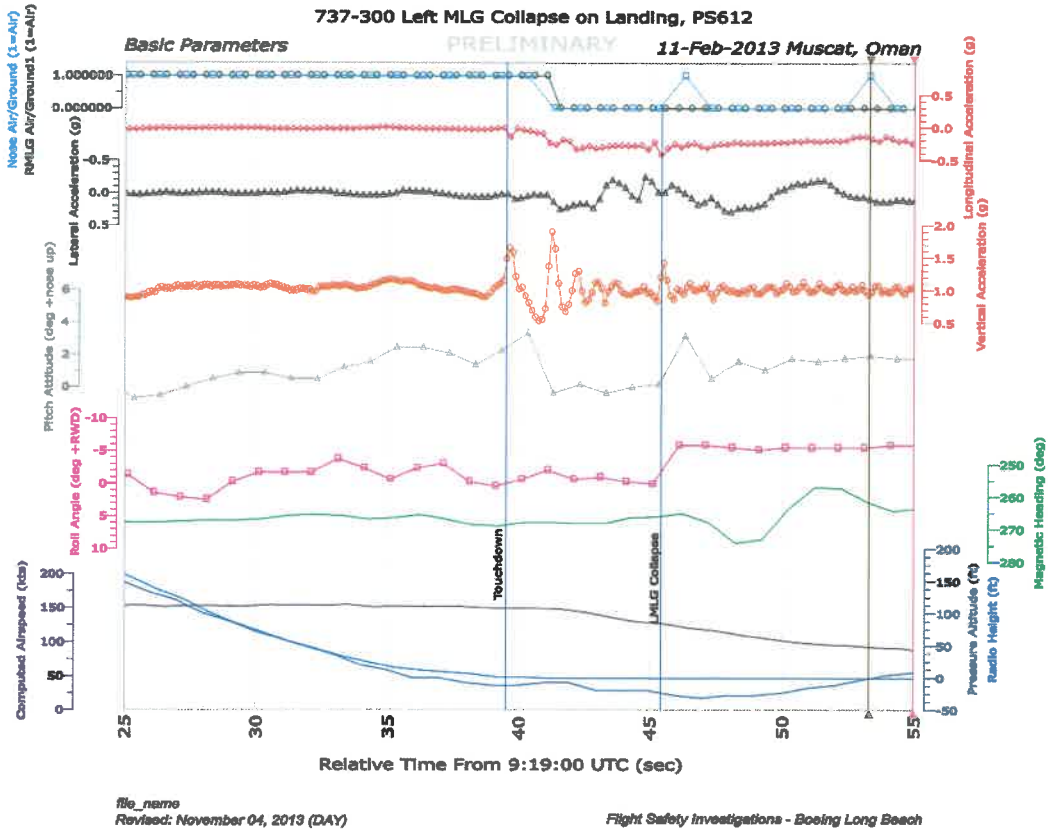
2. ANALYSIS

2.1 FDR of the mishap flight was analyzed by Boeing **(Appendix 'E')**. The salient analysis aspects are discussed in subsequent paragraphs whereas the graphical presentation of important parameters is shown on the following page.

2.2 The first contact of the aircraft with the runway occurred at 9:19:39.5 hrs and was indicated by the jump in vertical acceleration and a dip in longitudinal acceleration. The roll angle 0.5 seconds before touchdown was +0.4 degrees and 0.5 seconds after the beginning of the vertical acceleration spike was -0.7 degrees. Since the roll attitude during this time frame is predominantly negative (left wing down) and the pitch angle is positive (nose up) it was inferred that the touchdown was on the LMLG.

2.3 There is a spike in the vertical and longitudinal accelerations at 9:19:41.1 hrs. This coincides with a pitch angle near zero and a roll angle of -1.5 degrees. This is probably the time where the nose landing gear and right main landing gear tires contacted the runway. The next previous samples on the nose and Right Main Landing Gear (RMLG) air/ground sensors recorded "in air". The subsequent samples recorded "on ground".

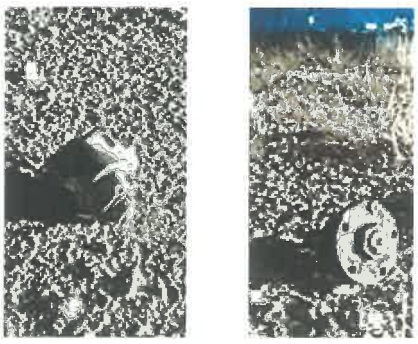
2.4 At 9:19:45.4 hrs the abrupt left-wing down roll to about -6.0 degrees was most probably due to LMLG collapse.



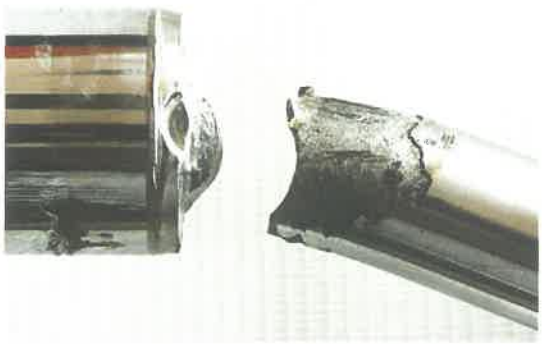
2.5 The Boeing FDR analysis report stated that 4-6 seconds between touchdown and Main Landing Gear (MLG) collapse (in this recording) is consistent with the timings of similar shimmy events that Boeing has seen in the past.

2.6 The variation of lateral accelerations after touchdown corroborates with the presence of shimmy.

2.7 The fractured shimmy damper actuator was found at a location prior to final stop corresponding to the initial stages after landing run. The visual examination of the fracture surface indicated an overload fracture.



Shimmy damper actuator



Fracture surface close up view

2.8 The failure mode analysis of the shimmy damper actuator was performed at Institute of Space Technology (IST), Failure Analysis Center (FAC). The FAC analysis report **(Appendix 'F')** concluded that fracture was a ductile overload failure under Tensile-

Bending stress. Fatigue failure was ruled out because of absence of beach marks and fatigue striations. The report further concluded that there was no evidence of brittle failure or stress corrosion cracking. There was no abnormality reported in chemical composition, micro structure and hardness value of the failed part.

2.9 The fractured Connecting Pin of Universal Link of LMLG was also submitted for failure mode and fractographic analysis to FAC. The FAC report **(Appendix 'G')** concluded that overall failure mechanism of the Connecting Pin was fast ductile fracture due to overload in bending/shear. The evidence of fatigue failure was not found during analysis of the available portion of the failed part.

Fractured Connecting Pin

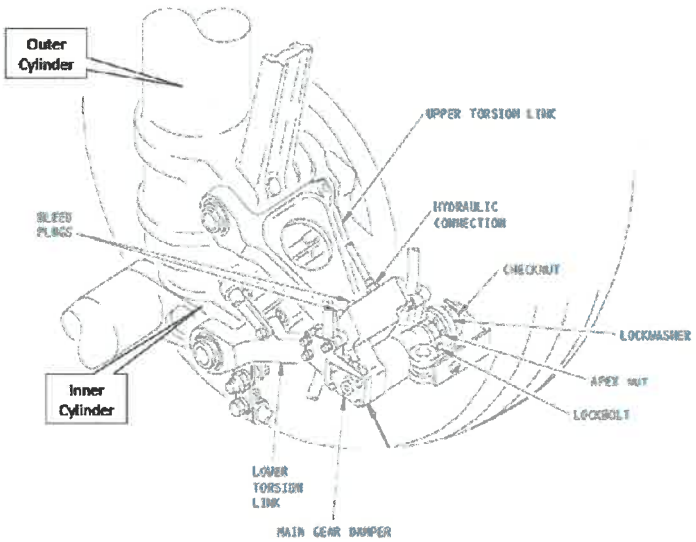
Close up view of fracture surface

2.10 The lower torsion link also got fractured. Part of the torsion link towards the shimmy damper could not be retrieved by the investigation team. Most probably this part separated after failure of torsion link and shimmy damper actuator and got thrown off the runway. However, part of the lower torsion link attached with the inner cylinder was available. It was visually examined and it also indicated an overload fracture.

Fractured Lower Torsion Link

2.11 The axel of the wheels is mounted on the inner cylinder. The torsion links and shimmy damper assembly prevents pivot of the inner cylinder inside the outer cylinder (torsional movement). The torsional vibrations are prevented by the shimmy damper. It is pertinent to mention that clearances of linkages of the shimmy damper are detrimental in

effectiveness and efficiency of the whole mechanism to prevent torsional vibrations of the wheel assembly.



Torsion Links and Shimmy Damper Assembly

2.12 Ineffective shimmy damper mechanisms due to trapped air, internal leaks/failures of damper, and more than specified clearances of the associated joints results in torsional vibrations, which are termed a shimmy event. If the vibrations approach the natural frequency of assembly then resonance phenomenon is excited which results into very large amplitude vibrations. The large amplitude vibrations exert excessive load on associated linkages, resulting into failure of the torsion links/shimmy damper actuator.

2.13 After failure of the torsion link or shimmy damper actuator the inner cylinder is no more restrained against torsional movement inside the outer cylinder. The rubbing marks on the wheel hub with runway surface indicated that wheel assembly pivoted almost perpendicular to aircraft movement direction, thus the wheels could not rotate with forward motion of the aircraft. The resultant friction force between the runway surface and tires pulled the landing gear rearward from lower side, while the aircraft was moving in forward direction thus causing failure of upper attachment fittings and collapse of the landing gear.

Rubbing marks on wheel hubs

2.14 The tear down examination of the shimmy damper was carried out and no evidence of damage to seals and internal mechanism was found, which if damaged can adversely affect the damping efficiency.

Shimmy damper internal seals and mechanism were found intact

2.15 The remaining failed parts of the LMLG were visually examined and it was concluded that they suffered overload fracture subsequent to Shimmy Damper Actuator/Torsion Link Failure and dragging of the pivoted wheel on its side on the runway.

2.16 The dimensional checks of the bushings in attachment point of upper and lower torsion links and corresponding bushings of the lugs on the inner and outer cylinder were performed. The measurements indicated excessive wear of bushings leading to more than specified clearances of the joints **(Appendix 'H')**.

2.17 Boeing maintenance instructions in applicable maintenance manual specify inspection and adjustment of Shimmy Damper Linkages in check-C, however, the frequency is also recommended to be enhanced in light of the Service Letter SL 737-SL-32-057. The latest revision of Service Letter recommends starting the certain AMM task card inspections/adjustments at A check and annually and then escalating incrementally to check-C based on service experience of the operator. The operator in this particular case was performing the subject checks as per AMM i.e. at check-C.

3. CONCLUSION

3.1 Findings

3.1.1 The initial touchdown was on LMLG and touchdown speed and sink rate were within structural tolerable limits.

3.1.2 The Shimmy damper actuator and lower torsion link fractured before the collapse of the LMLG.

3.1.3 The fracture surfaces of the failed landing gear parts indicated over load fracture pattern with no evidence of fatigue. The overload fractures were consequence of large amplitude vibrations (resonant vibration) due to shimmy during the mishap landing.

3.1.4 The shimmy damper internal mechanism was intact and there was no evidence of damage to its seals and piston, which if damaged can adversely affect the damping efficiency.

3.1.5 The dimensional measurements of torsion links attachment point bushings and corresponding lug bushings on the inner and outer cylinder of LMLG were found out of specified limit, indicating excessive wear which resulted in excessive play in the assembled shimmy damper and torsion link mechanism.

3.1.6 The excessive play in the shimmy damper mechanism was responsible for reducing the effectiveness of the mechanism and leading to shimmy event on LMLG just after the landing.

3.1.7 The large amplitude torsional vibrations resulted into failure of lower torsion link and shimmy damper actuator. After failure of the torsion link and shimmy damper actuator the LMLG wheels pivoted and were not able to rotate with forward motion of aircraft, thus resulting in collapse of the LMLG.

3.2 Cause Of Occurrence

3.2.1 The incident took place due to shimmy of left main landing gear. The excessive play at the joints of torsion links and shimmy damper mechanism was the cause of shimmy event.

4. SAFETY RECOMMENDATIONS

4.1. M/s PIAC is to ensure implementation of the following safety recommendations:

4.1.1. One time gap check/adjustment of apex joint of main landing gear torsion link, torsional free play check, shimmy damper bleeding and NDT of the upper and lower torsion links.

4.1.2. Reduction of interval of task cards 32-011-02-01, 32-011-02-02, 32-011-03-01, 32-011-03-02, 737-32-11-81-LH and 737-32-11-81-RH from check-C (4000 flight hrs) to check-4A (1000 flight hrs).