FINAL REPORT

ACCIDENT OF M/S SHAHEEN AIR INTERNATIONAL FLIGHT NL-142 B-737-400 AIRCRAFT REG # AP-BJO AT AIIAP, LAHORE ON 03RD NOVEMBER, 2015

Synopsis

The accident was reported to Safety Investigation Board (SIB), Pakistan by the Area Control Centre, Allama Iqbal International Airport (AIIAP), Lahore through telex and was notified in accordance with ICAO Annex-13 by SIB. Accredited Representative (ACCREP) was appointed by United States of America (state of manufacture & design). Director General Civil Aviation Authority (DG CAA), Pakistan issued Memorandum vide letter No. HQCAA/1901/374/SIB/658 dated 10th November, 2015 authorizing SIB to investigate the accident. President SIB along with Ops and Technical members of the inquiry team proceeded to the accident site on 03rd November, 2015 and collected all necessary evidence. The Captain and First Officer (FO) of the flight were sent for medical evaluation by Airport Manager, CAA, AIIAP, Lahore.

After touchdown, both main landing gears broke one after the other. Subsequently, the aircraft departed runway while resting on both engines and stopped 8302 ft from Runway Threshold (RWT), 197 ft left of runway centreline.

Cockpit crew landing the aircraft through unstabilized approach (high ground speed and incorrect flight path), low sink rate of left main landing gear (LMLG) and probable presence of (more than the specified limits) play in the linkages of shimmy damper mechanism lead to torsional vibrations / breakage of shimmy damper after touchdown. The resultant torsional excitation experienced by the LMLG due to free pivoting of wheels (along vertical axis) caused collapse of LMLG. The right main landing gear (RMLG) collapsed due departure of aircraft from the prepared surface of the runway towards unprepared surface (left side).

1. FACTUAL INFORMATION

1.1. **History of the Flight**. On 03rd November 2015, M/s Shaheen Air International Flight NL-142, Boeing 737-400 aircraft Reg # AP-BJO, was on a scheduled passenger flight from Karachi to Lahore. The flight landed on Runway 36L as Runway 36R was not available due to ILS CAT-III up-gradation. After touchdown, both main landing gears broke one after the other. Subsequently, the aircraft departed runway while resting on both engines and stopped 8302 ft from Runway Threshold (RWT), 197ft left of runway centreline. The nose landing gear, however, remained intact. All the passengers were safely evacuated through emergency procedure.

1.2. **Injuries to Persons**. No one from flight crew members or passengers was hurt during the accident. Few passengers received minor bruises during emergency evacuation through door slides and were treated by medical staff.

1.3. **Damage to Aircraft.** The fuselage of the aircraft remained intact. Both main landing gears got dislodged from the aircraft. The wing structure adjacent to the main landing gear attachment points was extensively damaged. Both engines sustained extensive damage because of dragging after landing gears collapse. The fuselage sustained damaged at right side in the tail section. The seats adjacent to the fuselage damage location were not occupied; therefore, there were no injuries.

Overview of damage to aircraft

1.4. **Other Damages**. No other damage was observed to any person, property or equipment on ground as result of the subject accident.

1.5. **Personnel Information**. The flight carried 121 souls onboard which included 114 passengers and 07 crew members. The details of cockpit crew are as under:

Captain		
Date of Birth	:	10th October, 1956
Age	:	59 Years
Type of License and validity	:	ATPL No 850 (A) Valid till 31st December, 2015
Type Rating	:	B-737/300-800
Mandatory Check (Last Sim)	:	23rd September, 2015 valid till 31st March, 2016
Flying Experience	:	P-1 Boeing 734 (3719 hrs) P-2 Boeing 734 (1140 hrs)
Total Flying Experience	:	19302:00 hrs
Medical Fitness and Validity	:	Class 1 valid 31st December, 2015
Medical Limitations	:	- Operational multi crew limitations - To wear spectacles during flying - Advised to reduce weight gradually

First Officer (FO)		
Date of Birth	:	28th October, 1981
Age	:	34 Years
Type of License and validity	:	ATPL No 1558 (A) Valid till 31st May, 2016
Type Rating	:	B-737/300-800
Mandatory Check (Last Sim)	:	13th June, 2015 Valid till 31st December, 2015
Flying Experience	:	P-2 Boeing 734 (410 hrs)
Total Flying Experience	:	2076 hrs
Medical Fitness and Validity	:	Class 1 valid 31st March, 2016
Medical Limitations	:	Advised to reduce weight gradually

1.5.1. The cockpit crew had valid licenses and medical fitness certificates. Captain and FO both had last flown on 31st October, 2015. They had 02 days rest time available (minimum 12 hrs required between flights) to them before undertaking mishap flight. Hence, CAA

Pakistan approved rules and regulations in respect of flight duty time limitation (FDTL) were adhered to. Therefore, the cockpit crew of mishap aircraft (MA) was not observed to be exposed to any undesired stress / fatigue prior to flight as a result of FDTL violation.

1.6. **Aircraft Information**. The mishap aircraft was maintained by the operator in accordance with the regulations of Pakistan Civil Aviation Authority. The Certificate of the Airworthiness No. 774 for Regular Air Transport, Charter Operations and Aerial Work Operation (Flying Training Only) category was valid till 24th October, 2016. The last Maintenance Review was conducted on 27th October, 2015 (51455 / 46502 hrs / cycles) and was valid till 26th April, 2016. Daily inspection of the aircraft was carried out at Karachi on 3rd November, 2015. There was no carried forward defect related to the landing gears, thrust reversers and wheel brakes. Pertinent aircraft and major parts maintenance and life information is as follows:

1.6.1.

Aircraft Make and Model	Boeing 737- 400
Aircraft Manufacturer S No.	27166
Year of Manufacture	9th December, 1992
Total Aircraft Hrs/Cycles	51585 / 46547
Last C check	On 27th October, 2014 at 48438/45008 hrs/cycles at PIA Karachi.
Last A Check	Check A-14 on 20th October, 2015 at 51455/46502 hrs/cycles at SEAMS Karachi
Left and Right Engine Type	CFM56-3C-1
Left Engine S No. 720540 Life	53606 / 39342 hrs / cycles
Right Engine S No. 725551 Life	45091 / 42261 hrs / cycles

1.6.2. The previous operator of the aircraft was Malaysian Airline (MAS) and aircraft was inducted by Shaheen Air International on 21st October, 2012 at 44474 flight hours and 43249 flight cycles.

1.6.3. The Shimmy damper assembly Part No. 65-44771-4, S. No. TSC3525 was installed on the LMLG of the aircraft. The Shaheen Air International record which was the same as delivered by the previous operator showed that serial number of the Damper Assembly installed on the aircraft was TSC3053. The document scrutiny did not show change of the component with current operator. Since the component is not a life limited part, therefore, its life history could not be tracked.

1.6.4. The records of life limited parts of LMLG Sr. No. MC04993P2505 and RMLG Sr. No. MC05702P2852 were reviewed. All life limited parts of the landing gears had sufficient remaining life. The maintenance / defect history of the aircraft for last one year was reviewed. There was no recorded defect related of LMLG shimmy.

1.6.5. The mass and centre of gravity of the aircraft were within prescribed limits.

1.6.6. The aircraft used Jet A-1 fuel.

1.7. **Metrological Information**. On 3rd November, 2015 the weather reports of Allama Iqbal International Airport, Lahore before departure from Jinnah International Airport (JIAP), Karachi and at the time of accident are as follows:

Time UTC	Weather Report					
	Vis	Outlook	Wind	Clouds	Temp	QNH
0136	1500M BECMG 1000M	Mist	Calm	SCT100	16/14	1017
0255 (T/Off)	1500M BECMG 2000M	Mist	Calm	SCT100	18/16	1018
0325	1000 M	Mist	Calm	SCT100	19/16	1018
0355	1200M BECMG 1500M	Mist	Calm	SCT100	21/16	1018
0425 (Ldg)	1500 M	Mist	Calm	SCT100	22/16	1018
0455	2000M BECMG 3000M	Mist	Calm	SCT100	23/16	1018

1.8. **Aids to Navigation**. Aircraft was equipped with serviceable VOR / DME and ILS equipment. Also, all required navigation aids were available and serviceable at AIIAP, Lahore prior to the landing of mishap aircraft except ILS for runway 36R which was not available due up-gradation work. The details of Radio Navigation and Landing Aids at AIIAP, Lahore are appended below:

OPLA AD 2.19 RADIO NAVIGATION AND LANDING AIDS

Type of aid. CAT of ILS (VAR VOR/ILS)	*ID*	*Frequency*	*Hours of operation*	*Site of transmitting antenna coordinates*	*Elevation of DME transmitting antenna*	*Remarks*
1	2	3	4	5	6	7
GP/TDME 36R	Dots / Dashes	333.8 MHz CH36X	H24	313032.40N 0742419.84E	230.61M	Coverage 7-10 NM
LLZ 36R ILS CAT II (1°E/1995)	ILA	109.9 MHz	H24	313223.46N 0742417.64E	-	Coverage 20 NM
MM 36R	Dashes	75 MHz	H24	-	-	-
L	LO	338 KHz	H24	-	-	-
OM 36R	Dashes	75 MHz	H24		-	-
NDB	LA	268 KHz	H24	*3130.4N 07423.0E		
DVOR/DME (1°E/1995)	LA	112.7 MHz CH74X	H24	312959.00N 0742400.07E	222.70M	Coverage 200 NM

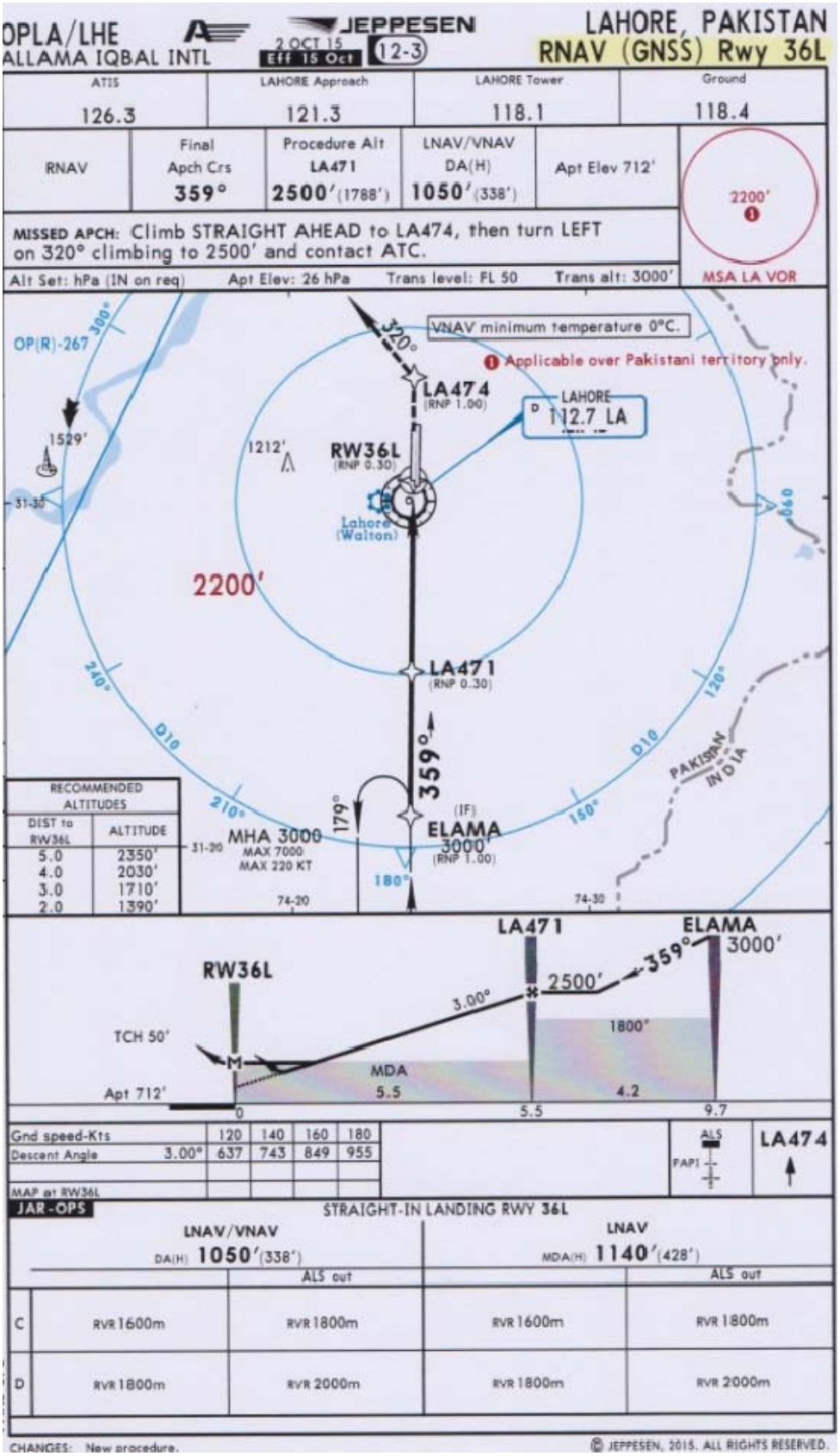
1.9. **Communications**. Following communication aids were available and found serviceable at AIIAP, Lahore at the time of accident of AP-BJO.

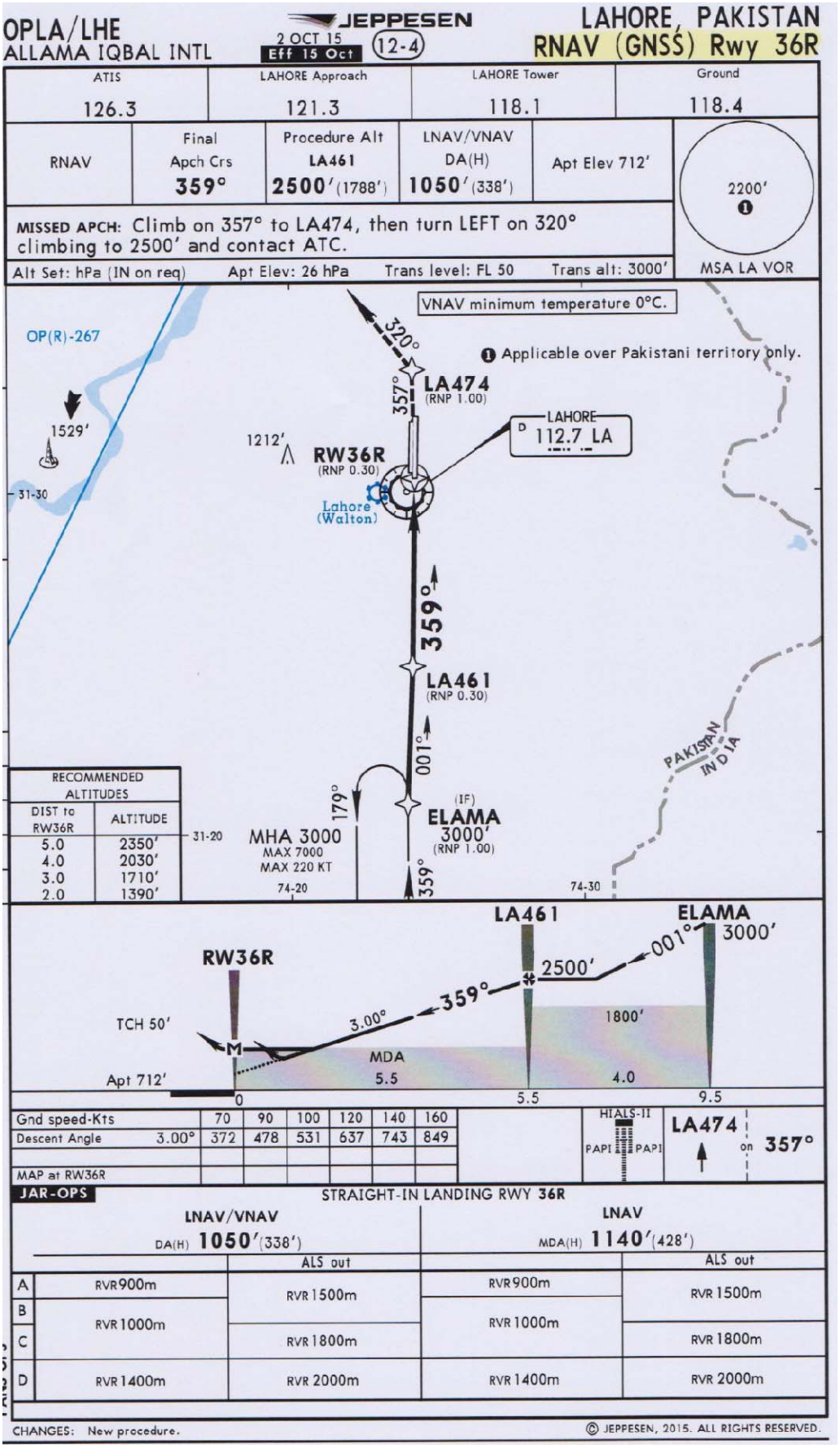
OPLA AD 2.18 ATS COMMUNICATION FACILITIES

Service designation	*Call sign*	*Frequency*	*Hours of operation*	*Remarks*
1	2	3	4	5
TWR	Lahore Tower	118.1 MHz	H24	Primary
TWR	Lahore Tower	118.875 MHz	H24	Secondary
Apron	Lahore Ground	118.4 MHz	H24	Primary
Apron	Lahore Ground	121.8 MHz	H24	Secondary
ATIS	ATIS	126.3 MHz	H24	
APP	Lahore APP	121.3 MHz	H24	Primary
	Lahore APP	125.3 MHz	H24	Secondary
	Lahore APP	121.5 MHz	H24	Emergency
BS	Radio	630 KHz	HX	0130-1900 HR
BS	Pakistan	1090 KHz	HX	Variable SKED

1.10. **Aerodrome Information**.

1.10.1. The AIIAP, Lahore VOR DME and RNAV approach charts for runway 36R/L are appended below:




OPLA/LHE
ALLAMA IQBAL INTL
JEPPESEN
2 OCT 15
Eff 15 Oct
12-4
LAHORE, PAKISTAN
RNAV (GNSS) Rwy 36R
ATIS 126.3
LAHORE Approach 121.3
LAHORE Tower 118.1
Ground 118.4
RNAV
Final Apch Crs 359°
Procedure Alt LA461 2500′ (1788′)
LNAV/VNAV DA(H) 1050′ (338′)
Apt Elev 712′
2200′
MISSED APCH: Climb on 357° to LA474, then turn LEFT on 320° climbing to 2500′ and contact ATC.
Alt Set: hPa (IN on req)
Apt Elev: 26 hPa
Trans level: FL 50
Trans alt: 3000′
MSA LA VOR
VNAV minimum temperature 0°C.
Applicable over Pakistani territory only.
OP(R)-267
320°
357°
LA474
(RNP 1.00)
LAHORE
112.7 LA
1529′
1212′
RW36R
(RNP 0.30)
Lahore (Walton)
31-30
359°
LA461
(RNP 0.30)
001°
179°
(IF)
ELAMA
3000′
(RNP 1.00)
359°
MHA 3000
MAX 7000
MAX 220 KT
31-20
74-20
74-30
PAKISTAN
INDIA
RECOMMENDED ALTITUDES
DIST to RW36R | ALTITUDE
5.0 | 2350′
4.0 | 2030′
3.0 | 1710′
2.0 | 1390′
LA461
ELAMA
3000′
001°
2500′
359°
RW36R
TCH 50′
3.00°
1800′
MDA
5.5
4.0
Apt 712′
0
5.5
9.5
Gnd speed-Kts | 70 | 90 | 100 | 120 | 140 | 160
Descent Angle 3.00° | 372 | 478 | 531 | 637 | 743 | 849
MAP at RW36R
HIALS-II
PAPI PAPI
LA474 on 357°
JAR-OPS
STRAIGHT-IN LANDING RWY 36R
LNAV/VNAV DA(H) 1050′ (338′)
LNAV MDA(H) 1140′ (428′)
ALS out
A RVR 900m RVR 1500m RVR 900m RVR 1500m
B RVR 1000m RVR 1000m
C RVR 1800m RVR 1800m
D RVR 1400m RVR 2000m RVR 1400m RVR 2000m
CHANGES: New procedure.
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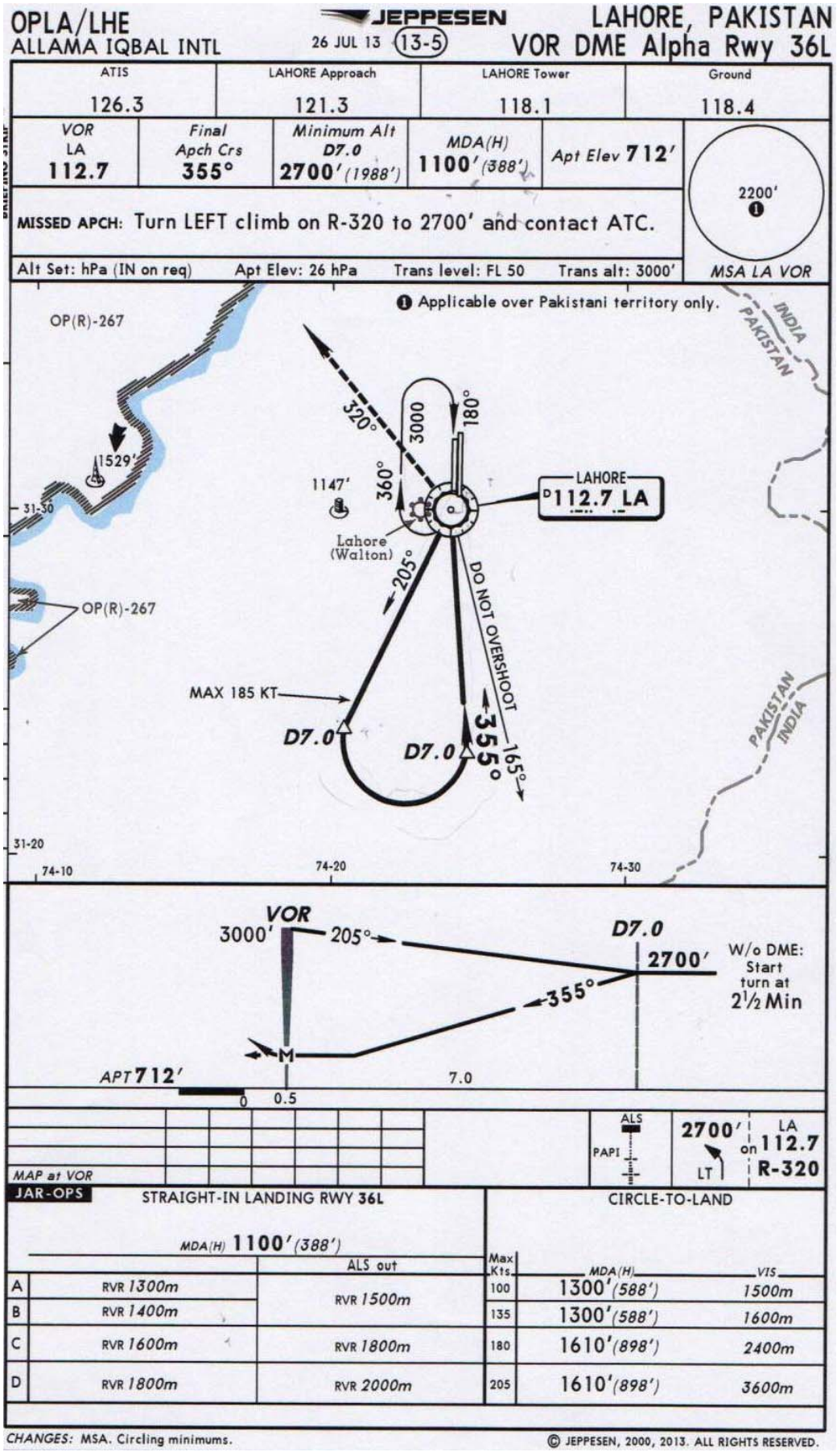
OPLA/LHE
ALLAMA IQBAL INTL
JEPPESEN
26 JUL 13 (13-5)
LAHORE, PAKISTAN
VOR DME Alpha Rwy 36L
ATIS 126.3
LAHORE Approach 121.3
LAHORE Tower 118.1
Ground 118.4
VOR LA 112.7
Final Apch Crs 355°
Minimum Alt D7.0 2700′ (1988′)
MDA(H) 1100′ (388′)
Apt Elev 712′
2200′
MISSED APCH: Turn LEFT climb on R-320 to 2700′ and contact ATC.
Alt Set: hPa (IN on req)
Apt Elev: 26 hPa
Trans level: FL 50
Trans alt: 3000′
MSA LA VOR
1 Applicable over Pakistani territory only.
OP(R)-267
INDIA
PAKISTAN
320°
3000
180°
360°
1529′
1147′
LAHORE
112.7 LA
Lahore (Walton)
205°
DO NOT OVERSHOOT
355°
165°
MAX 185 KT
D7.0
D7.0
PAKISTAN
INDIA
31-30
31-20
74-10
74-20
74-30
VOR
3000′
205°
D7.0
2700′
355°
W/o DME: Start turn at 2½ Min
APT 712′
7.0
0
0.5
MAP at VOR
ALS
PAPI
LT
2700′ on LA 112.7 R-320
JAR-OPS
STRAIGHT-IN LANDING RWY 36L
MDA(H) 1100′ (388′)
ALS out
A RVR 1300m RVR 1500m
B RVR 1400m
C RVR 1600m RVR 1800m
D RVR 1800m RVR 2000m
CIRCLE-TO-LAND
Max Kts
MDA(H)
VIS
100 1300′ (588′) 1500m
135 1300′ (588′) 1600m
180 1610′ (898′) 2400m
205 1610′ (898′) 3600m
CHANGES: MSA. Circling minimums.
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1.10.2. The AIIAP, Lahore detailed aerodrome data is appended below:

OPLA AD 2.12 RUNWAY PHYSICAL CHARACTERISTICS

Designations RWY NR	True bearing	Dimensions of RWY (M)	Strength (PCN) and surface of RWY and SWY	THR coordinates	THR elevation and highest elevation of TDZ of precision APP RWY
1	2	3	4	5	6
18L	180°	3360 x 46	PCN 85/R/B/X/U (concrete)	313211.94N 0742417.44E	THR 216.9M / 712 FT
36R	360°			313023.30N 0742415.49E	THR 215.1M / 706 FT
18R	180°	2743 x 46	PCN 55/F/C/X/T	313202.14N 0742410.18E	THR 216.5M / 710 FT
36L	360°			313033.13N 0742408.60E	THR 214.8M / 705 FT

OPLA AD 2.14 APPROACH AND RUNWAY LIGHTS

Designations RWY NR	APCH LGT type LEN INTST	THR LGT colour WBAR	VASIS (MEH) PAPI	TDZM LGT LEN	RWY Centre line LGT Length, spacing, colour, INTST	RWY EDGE line LGT Length, spacing, colour, INTST	RWY End LGT spacing colour WBAR	SWY LGT LEN (M) colour	Remarks
1	2	3	4	5	6	7	8	9	10
18L	SALS 420 M LIL	GREEN	PAPI Both side 3°	-	3360, 30m. White/ Red	3360, 60m, White	RED	-	-
36R	PALS CAT II 900M LIH	GREEN	PAPI Both side 3°	900 m.	3360, 30m. White/ Red	3360, 60m, White	RED	-	-
18R	SALS 420 M LIL	GREEN	PAPI 3°	-	-	2743, 60m, White LIL	RED	-	-
36L	SALS 420 M LIL	GREEN	PAPI 3°	-	-	-	RED	-	Strobe lights

OPLA AD 2.19 RADIO NAVIGATION AND LANDING AIDS

Type of aid. CAT of ILS (VAR VOR/ILS)	ID	Frequency	Hours of operation	Site of transmitting antenna coordinates	Elevation of DME transmitting antenna	Remarks
1	2	3	4	5	6	7
GP/TDME 36R	Dots / Dashes	333.8 MHz CH36X	H24	313032.40N 0742419.84E	230.61M	Coverage 7-10 NM
LLZ 36R ILS CAT II (1°E/1995)	ILA	109.9 MHz	H24	313223.46N 0742417.64E	-	Coverage 20 NM
MM 36R	Dashes	75 MHz	H24	-	-	-
L	LO	338 KHz	H24	-	-	-
OM 36R	Dashes	75 MHz	H24		-	-
NDB	LA	268 KHz	H24	*3130.4N 07423.0E		
DVOR/DME (1°E/1995)	LA	112.7 MHz CH74X	H24	312959.00N 0742400.07E	222.70M	Coverage 200 NM

1.11. **Flight Data Recorders**. Flight Data Recorder (FDR) Part Number 980-4700-003 S. No. 2767 and Cockpit Voice Recorder (CVR) Part Number 980-6020-001 S. No. 0521 were intact. The data from both the recorders was successfully retrieved and utilized for the purpose of the investigation.

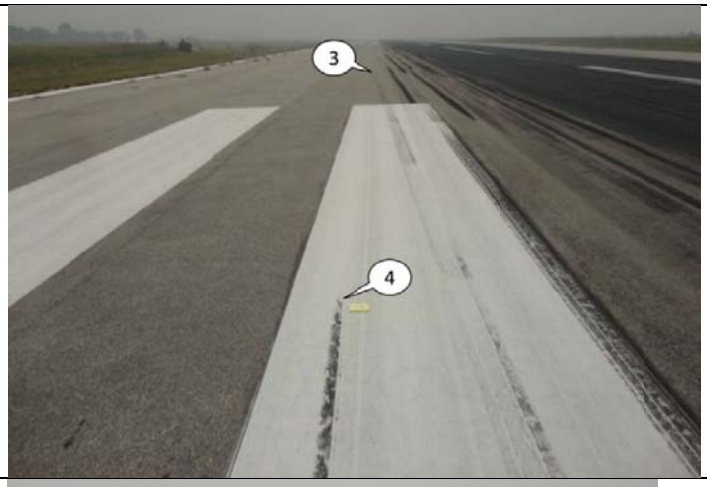
1.12. **Wreckage and Runway Marks Information**. The first discernable aircraft landing mark on the runway was right outer (No.4) tyre mark, approximately 1394 ft after the RWT and 28 ft towards the left of runway Centre Line (CL).

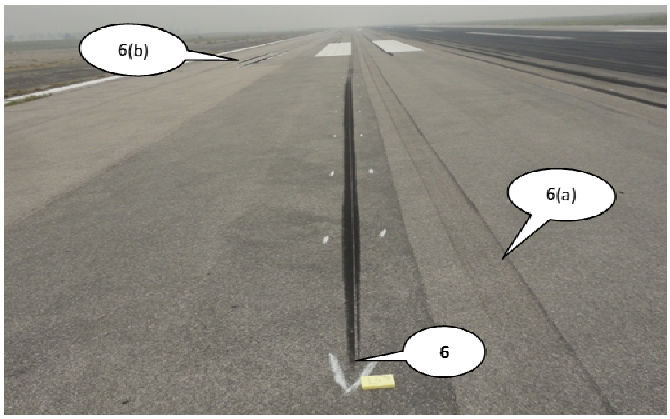
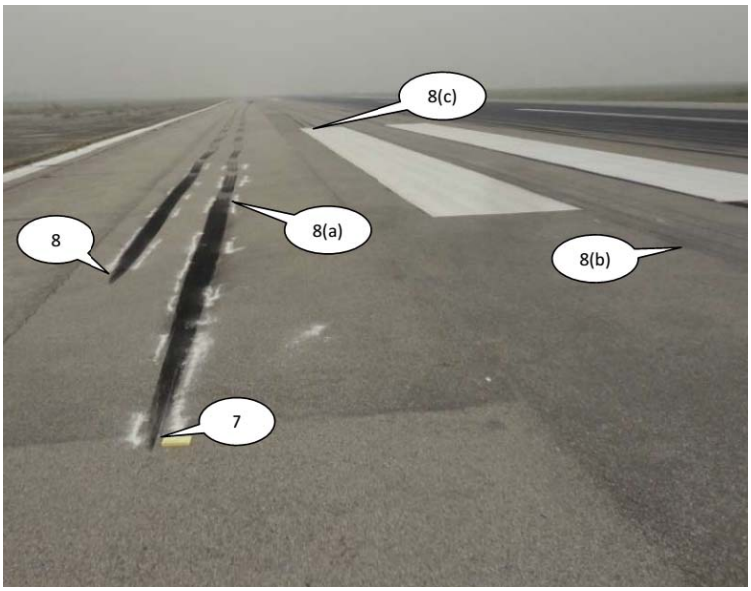
1.12.1. The ground marks indicated that the LMLG collapsed on the runway and aircraft kept moving forward and drifting left with left engine dragging on the runway. The RMLG collapsed while the aircraft was moving on fair weather strip on left side of the runway. The aircraft then dragged forward on both engines till it came to a final stop at approximately 8302 ft from RWT and 197 ft left of CL.

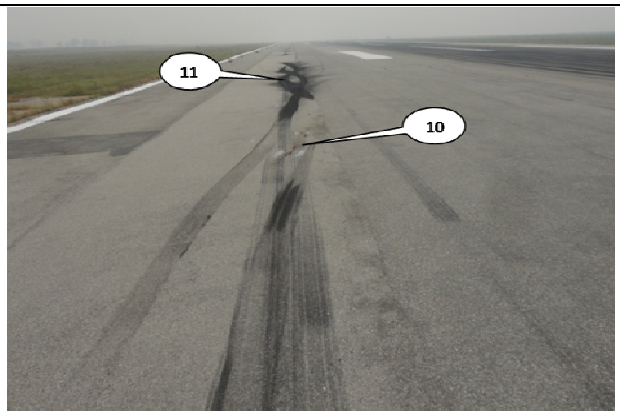
1.12.2. The dislodged landing gears and some of the lower parts of engines / cowlings were found along the aircraft ground track. The rest of the aircraft structure remained intact. Following pictures depict the significant points along the aircraft ground path and location of different dislodged parts.

Aircraft ground track and location of dislodged parts

1.12.3. **Distances and detailed information of marked points along aircraft ground track**.

1. Right outer (No. 4) tyre mark starts 1394 ft after Runway Threshold (**RWT**), 28 ft left of Runway Centre line (**CL**). After about 25 ft tyre marks pattern, gradually becomes lighter and repeats after small gaps till white line. **2**. Right inner (No. 3) tyre dark mark start 24 ft from point 1 and is 31 ft left of CL. Mark is 24 ft long, then there is 5 ft gap and then dark mark continues for 75 ft. Its end point is 34 ft left of CL.	
3. End point of right outer (No. 4) tyre mark (1656 ft from RWT). **4**. End point of right inner (No. 3) tyre mark (1578 ft from RWT and 34 ft left of CL).	
5. Very light right outer (No. 4) mark started again after 82 ft from point 3 (1738 ft from RWT), 33 ft left of CL. Right inner (No. 3) and left tyre marks not visible around here. **5(a)**. Right inner (No. 3) dark tyre mark is visible at distance, before left white line.	

6. Right inner (No. 3) dark tyre mark started again, 4443 ft from 1 (1837 ft from RWT) and 39 ft left of CL. **6(a)**. Right outer (No. 4) tyre mark is continuing very light from point 5. **6(b)**. Left wheel mark is visible at distance.	
7. Left main inner (No. 2) tyre mark started 184 ft from point 6 (2020 ft from RWT, 56 ft left of CL). **8**. Left main outer (No. 1) tyre mark started about 10 ft after point 7. **8(a)**. Straight mark of both wheels continues about 30 ft from point 7 (2050 ft from RWT, 56 ft left of CL), and then mark lightens and is zigzag. **8(b)**. Right wheel marks are very light. **8(c)**. Nose wheel dark mark started near end of left thick line.	
9. Nose wheel marks, first right tyre (2122 ft from RWT, 46 ft left of CL) and then left tire. **9(a)**. Right main tyre mark very light. **9(b)**. Left main tyres' longer zigzag pattern and light marks also visible.	

10. Left wheel hub marks (2434 ft from RWT, 49 ft left of CL). **11**. Very dark left wheels crisscross marks started (2444 ft from RWT, 49 ft left of CL).	
12. Crisscross pattern is about 92 ft long. Ends at 2535 ft from RWT.	
13. Left engine (No. 1) touched runway (2650 ft from RWT, 56 ft left of CL).	
14. Left wheel tyre piece (3162 ft from RWT, 26 ft left of CL).	

15. Upper torsion link forward piece (3556 ft from RWT, 105 ft left of CL).	
16. Shimmy damper piston rod end piece (3818 ft from RWT, 62 ft left of CL).	
17. Shimmy damper was found (4474 ft from RWT, 16 ft right of CL).	
18. Left main landing gear (4540 ft from RWT, 52 ft left of CL).	
19. Left engine (No. 1) rub mark entered unprepared surface on left of runway (6468 ft from RWT, 115 ft left of CL). **20**. Nose wheel entered unprepared surface on left of runway (6711 ft from RWT)	

21. Right wheel entered unprepared surface on left of runway (6878 ft from RWT).	
22. Right wheel tyre piece (6996 ft from RWT, 85 ft left of CL)	
23. Engine cowling , thrust reverser and miscellaneous hardware debris scattered around (7390 ft from RWT)	
24. Right main landing gear (7452 ft from RWT, 128 ft left of CL)	

25. Aircraft final position on left side of the runway (8302 ft from RWT, 197 ft left of CL).	 

1.13. **Medical and Pathological Information**. There was no injury to any passenger or crew member. The Cockpit Crew (Captain and First Officer), however, were taken to hospital and necessary medical evaluations were conducted. **There were signs of Alcohol consumption (in the blood test) by the Captain prior to undertaking the mishap flight**. The First Officer's medical evaluation did not reveal any significant abnormality. The contribution of these medical factors in causation of accident is discussed in detail in Medical Analysis.

Injuries	Crew	Passengers	Others	Total
Fatal	--	--	--	--
Serious	--	--	--	--
Minor	--	--	--	--
None	02	114	05	121

1.14. **Fire**. Pre-impact, in-flight or post impact fire was neither reported by the cockpit crew of MA nor any such signs were observed by the Investigation Team Members at the crash site.

1.15. **Survival Aspects**.The aircraft fuselage remained intact and passengers were evacuated using emergency slides. The row of seats adjacent to fuselage damage location was not occupied and therefore, no passenger was injured.

1.16. **Tests and Research**. Fractographic and failure mode analysis of selected parts was performed. The results are incorporated in the technical analysis.

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

1.18. **Additional Information**.

1.18.1. **ATC Tape Extracts**. AIIAP Lahore ATC Tower / Approach Radar Tape Extracts and recordings were retrieved and analysed.

1.18.2. **Crew Resource Management (CRM).** At the time of occurrence, the Captain was the Pilot Flying (PF) whereas First Officer was Pilot Monitoring (PM). Both the cockpit crew had valid CRM certification.

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

2. ANALYSIS

2.1. Operational Analysis

2.1.1 The mishap flight was a scheduled passenger flight from Karachi to Lahore. The scheduled departure time from Karachi was 0300 UTC and it was to arrive at Lahore at 0445 UTC.

2.1.2 The FO reported at Flight Operations at 0200 UTC and the Captain arrived at 0215 UTC. Whereas, both were required to be in Flight Operations at 0130 UTC and on the aircraft at 0215 UTC as per SAI Ops Manual (Part A) Edition II Ch.7 P.10 para 7.7.1. Due to their late arrival, short time was available to them for detailed pre flight brief and preparation.

2.1.3 The FO received Flight Plan, obtained latest weather information & NOTAMS. The METAR received by FO when he reported at Flight Operations indicated OPLA visibility 1500 M with a reducing trend to 1000 M which was below the minimum required (1600 M) for landing at OPLA on runway 36L through a VOR DME approach. However, at the time of take off i.e. 0300 UTC from JIAP Karachi, the destination aerodrome had 1500 M visibility with misty outlook and increasing trend to 2000 M.

2.1.4 The Captain was Pilot Flying (PF) and FO was Pilot Monitoring (PM) for the flight. The Captain conducted a short departure brief which included taxi route and Standard Instrument Departure (SID). He did not discuss destination aerodrome weather conditions, diversion to alternate aerodrome and landing on runway 36L through VOR DME which was an uncommon practice requiring attention.

2.1.5 According to Flight Plan the flight was to cruise at FL 330 and total flight time to destination was 1 hour 23 minutes. Only one alternate aerodrome was planned which was Peshawar (OPPS). The weather forecast for OPPS indicated rain.

2.1.6 The Flight took off at 0308 UTC and carried out instrument departure. The flight climbed to its cruising altitude as planned and remained uneventful during cruise. Before initiating descent as per flight plan, the cockpit crew obtained latest weather of destination aerodrome (OPLA) which mentioned visibility 1200 meters. This visibility was below the minimum required (1600m) for carrying out a VOR DME approach and necessitated decision for diversion to alternate aerodrome. The cockpit crew decided to continue for the destination. At this time the flight was with Karachi Area Control Centre (ACC).

2.1.7 At 0359:02 UTC the flight changed over to Lahore ACC. Lahore ACC cleared the mishap flight for arrival to Lahore for VOR DME approach runway 36L. The Captain asked FO to request Lahore ACC for “ten miles finals runway 36R, initially” which was complied. Lahore ACC declined clearance for runway 36R and informed cockpit crew that the requested runway was not available due scheduled maintenance and also passed on latest weather as “ Lahore weather warning for poor visibility due mist up till 0700E and present visibility 1200 meters”. According to FO they were planning to follow ILS procedure for runway 36R with intention to break off after acquiring visual with the runway and landing at runway 36L. This was a non standard procedure.

2.1.8 At 0404:29 the FO tried twice to contact Sialkot International Airport (an airport in near vicinity of AIIAP, Lahore) to obtain her weather (the alternate aerodrome as per flight plan was Peshawar). The radio contact with Sialkot was not established. At this time, the FO discussed with the Captain that in case of diversion their alternate aerodrome was Peshawar and it required additional fifty minutes of flying time.

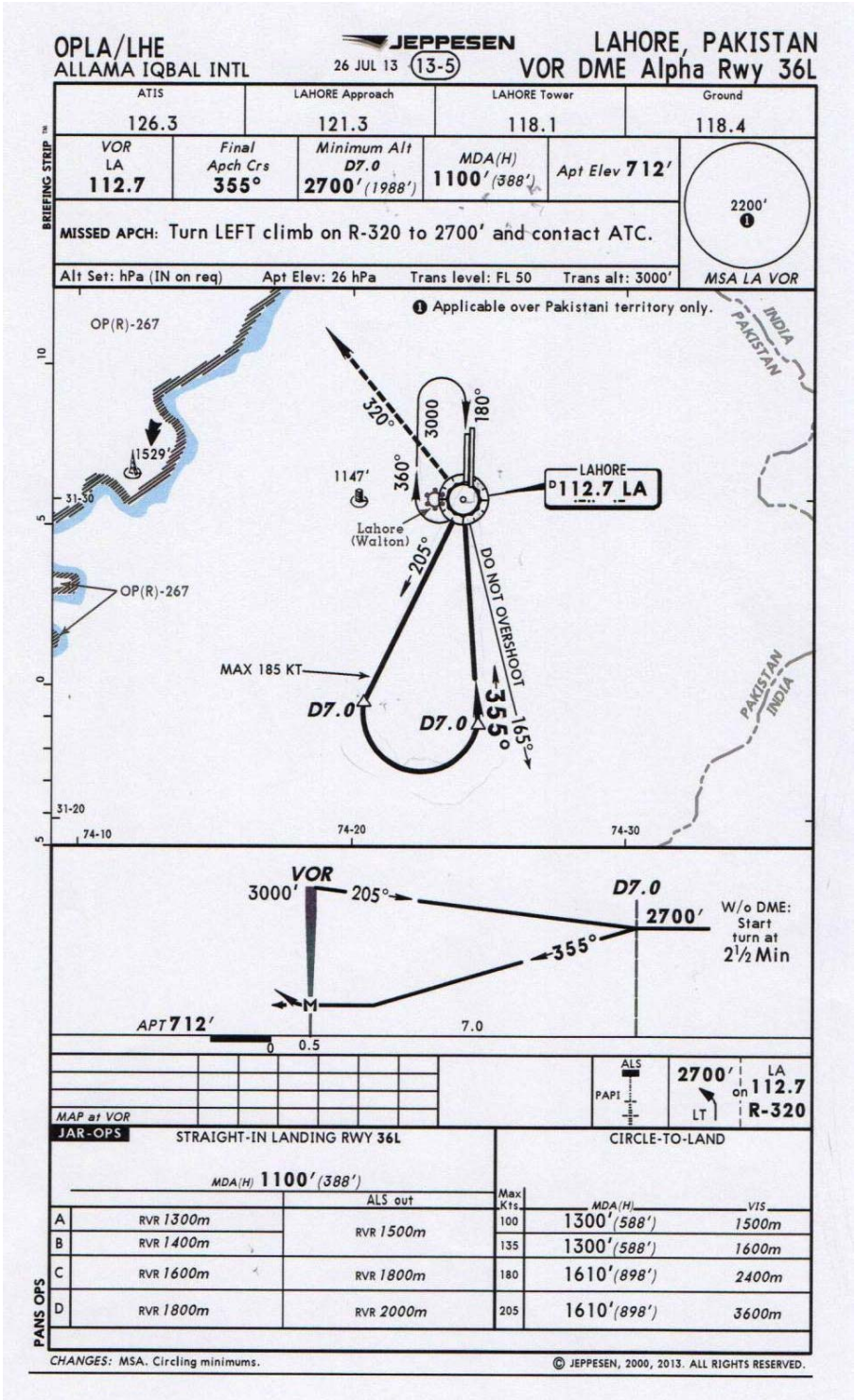
2.1.9 At 0404:57 the FO asked Captain whether they had to go for RNAV. The Captain told him to request for RNAV approach. The aircraft was not equipped with mandatory navigation equipment (GNSS) required for carrying out RNAV approach and the operator had also issued necessary instructions in this regard, also this decision was contrary to recommended procedure i.e. ICAO Doc 9613 para 3.4.1.1 and 3.4.1.2. At this stage, when the FO was cross checking the arrival procedure on Flight Management Guidance Computer (FMGC) he apprised the captain that by mistake the captain had selected runway 18L instead of runway 36L, which was later on accepted by the Captain and the FO was advised to change the arrival procedure. The conversation between Captain and FO at this time indicates that the Captain had difficulty in identifying / reading and feeding the correct arrival procedure due to inability in concentration.

2.1.10 The FO was continuously found to be prompting the Captain for decision making. In order to calculate RVR for VOR DME approach runway 36L as given in Jeppesen Chart 13-5, the FO calculated RVR as 1800 meters by multiplying visibility (1200m) with 1.5. He lacked the knowledge of RVR calculation procedure and did not consider availability of other services at runway 36L, like high intensity approach lighting system (HIALS) or high intensity runway lights (HIRL) as mentioned in Jeppesen General Airway Manual p.200 appended below. Incorrect calculation of RVR was not corrected by the Captain as well.

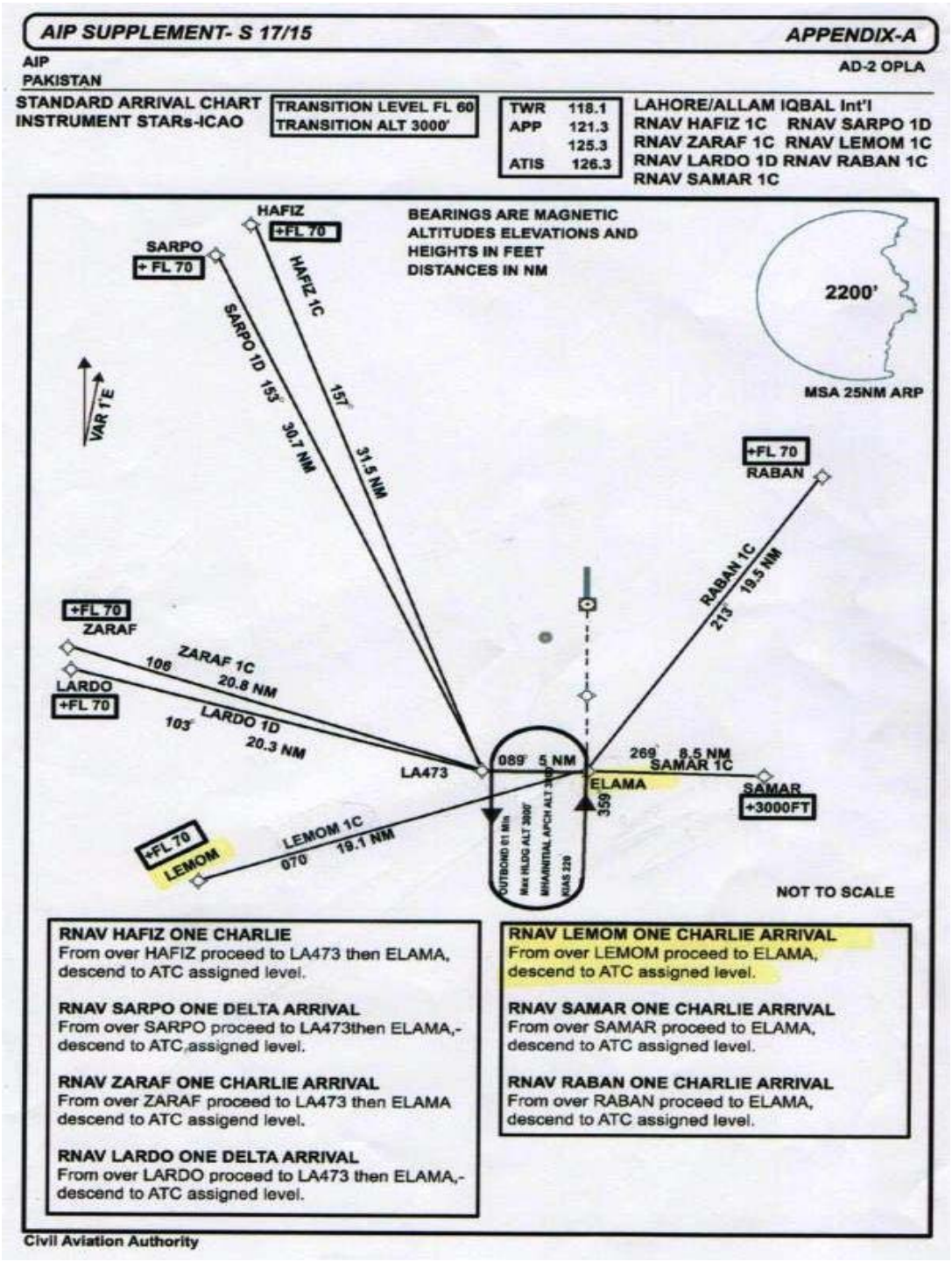
CONVERSION OF REPORTED MET VIS TO RVR/CMV

Lighting elements in operation	RVR/CMV = Reported MET VIS x	
	Day	Night
HIALS and HIRL	1.5	2.0
Any type of lighting installation other than above	1.0	1.5
No lighting	1.0	Not Applicable

2.1.11 As per criteria mentioned in above table, RVR was same (1200m) as the reported visibility due to other type of lighting system (SALS 420M) installed on runway 36L. The required RVR for carrying out a VOR DME approach by Cat C airplane at runway 36L of OPLA as per Jeppesen Chart 13-5 was 1600m.



2.1.12 At 0412:15 UTC, the cockpit crew changed over to Lahore Approach Frequency as cleared by Lahore ACC. As the FO contacted Lahore Approach and informed that the flight was handed over to her and it was descending from FL 240 to FL150. Lahore Approach found the flight being right of track and inquired cockpit crew by asking them, if they were right of track. The Captain quickly asked FO to tell Lahore Approach that they were following RNAV procedure for runway 36L. The FO complied with the Captain's instructions. Lahore Approach acknowledged that and directed the FO to report position LEMOM while continuing descend to FL 70. Lahore approach acknowledged Captain's decision to follow RNAV and did not pursue for her previous clearance for VOR DME approach runway 36L and change of procedure to RNAV at this stage.



2.1.13 At 0416:52 UTC Lahore Approach cleared mishap flight for RNAV LEMOM ONE CHARLIE arrival runway36L, “descend down to 3000 ft on QNH 1018 hecta pascal and report position ELAMA”. The FO acknowledged the approach by correctly reading back. The flight turned right from hdg 040° to 070° while descending through 10300ft, with speed reducing through 273 kts and at a distance 27.4 NM from thresholds runway 36L.

2.1.14 At 0420:18 UTC Lahore Approach observed the flight passing through FL85 at 20 track miles which was approx 2000-2500 ft higher than the assigned altitude. At this time, the cockpit crew selected Flaps-1, 2 and 5 in quick succession in order to increase the ROD, however speed brakes were not used here. Lahore Approach contacted cockpit crew to reconfirm whether they will be able to make approach or will discontinue due to being high.

The Captain immediately prompted FO to reply by saying “Affirmative”. The FO replied as “affirmative, we can make it”.

2.1.15 At this stage, it is established that the flight was neither following the track (it was right of track) nor the assigned altitudes as per ATC clearance / relevant chart. The cockpit crew lacked desired situational awareness due to stress of poor visibility combined with loss of concentration of Captain probably due to effects of alcohol, yet they wanted to continue for the landing at destination airport.

2.1.16 At 0420:47 UTC the FO suggested the Captain to use the Speed Brake so that the flight can quickly descend to desired altitude. The captain in response voiced “haye...haye...haye” indicating that he was exhausted and unable to cope up with the difficult situation.

2.1.17 At 0422:05 UTC the Captain asked FO to lower Flaps-10 and lower Landing Gears. The FO complied with the instructions and confirmed. The Captain again voiced “haye...haye...haye”. At this stage, they also lowered Flaps-15, Landing Light - On and Flaps-30. The Captain asked FO to complete landing checklist which was successfully done by the FO.

2.1.18 At 0422:50 UTC the flight was approaching over ELAMA at 5400 ft, 9.7NM from thresholds (runway 36L) at speed approx 180kts.

2.1.19 At 0422:53 UTC when the flight reported her position over ELAMA, the Lahore Approach Control observed her to be at 5000 ft altitude instead of already cleared 3000 ft. The duty controller cautioned cockpit crew by telling them that their altitude at ELAMA should have been 3000 ft whereas he had observed it to be 5000 ft. He also advised them to continue at pilot’s own responsibility; if they end up carrying out missed approach, they should continue to maintain runway heading and also advised to contact tower. By these instructions, it appears that the Lahore Approach Controller was quite certain that the flight would end up carrying out missed approach due to being very high on approach.

2.1.20 After reaching over ELAMA, the flight turned left heading 355° and lowered Flaps-30. The speed at this time was 180 kts and flight was descending through 5000 ft.

2.1.21 At 0423:52 UTC the Captain disengaged the autopilot at 9NM from RWT to lose the excess height by increasing ROD also executed turns to acquire the runway. However, the captain’s decision to disengage autopilot at this stage without being visual with the runway increased his workload. Resultantly, the aircraft descended with very high ROD from 2000 – 3500 ft/min. The excessive ROD with Flaps-30 selected resulted in exceeding flap speed limit.

2.1.22 By the time the flight reached 4.6 NM from runway threshold lines, her parameters were hdg 356°, Ht 1211ft, speed 170 kts and ROD 1300 ft/min which were almost correct at this distance from the runway but still not visual with the runway (the cockpit crew was actually carrying out VOR DME approach against their R/T communication of RNAV approach for which the aircraft was not suitably equipped). The Captain kept flying the aircraft with no visual cues due poor visibility, increased stress level, loss of situational awareness and reduced mental ability which led to ending up low on approach with high speed. Important flight parameters on final approach below 1000 ft AFE are tabulated below which indicate that the approach had become unstabilized.

Ht (ft) AFE	Distance (NM) from RWT	Computed Speed (Kts)	ROD (ft/min)	Hdg (Mag)		Bank Angle (deg)	Comments
992	4.1	161	1050	360	360	1.1 L	**High speed by 20kts and below glide slope**
951	4.01	159.5	1020	358	360	6 L	
900	3.87	158.5	930	357	360	2.8 L	
852	3.74	158	780	354	360	7.7 L	
797	3.56	157	630	351	360	6 L	
753	3.38	155	570	345	360	10.9 L	Low on approach, opened power to reduce ROD
700	3.16	153	360	344	360	1.4 L	
649	2.56	152	750	340	360	4.2 L	
604	2.43	153	900	339	360	2.8 L	
547	2.3	155	900	340	360	0	
496	2.16	155	810	340	360	0.7 L	
448	1.99	154	570	340	360	2.1 R	Low on Approach and angling ,started turning right
401	1.46	151	390	350	360	22.1 R	
347	1.24	152	690	004	360	21.8 R	**Speed started increasing**
303	1.11	155	630	009	360	9.1 R	
248	0.8	154	750	016	360	5.3 R	
191	0.62	154	900	013	360	5.6 L	Ended up on right, started turning left
147	0.49	156	660	006	360	12 L	
101	0.22	163	540	354	360	9.1 L	
44	-0.02	168	808	357	360	3.9 L	**On RWT with high speed by 25 Kts and high ROD**
0	-0.21	165	328	002	360	7.0 R	

2.1.23 The above mentioned chart clearly depicts that below 1000 ft AFE the MA flew an unstabilized approach keeping in view large variations in speed, heading, and bank angle. This unstablized approach warranted a go around as per criteria given by Boeing Company and, which mentions...

"All approaches should be stabilized by 1,000 ft AFE in instrument meteorological conditions (IMC) and by 500 ft AFE in visual meteorological conditions (VMC). An approach is considered stabilized when all of the following criteria are met:

- The airplane is on the correct flight path
- Only small changes in heading and pitch are required to maintain the correct flight path
- The airplane should be at approach speed. Deviations of + 10 kts to – 5 kts are acceptable if the airspeed is trending toward approach speed
- The airplane is in the correct landing configuration
- sink rate is no greater than 1,000 fpm; if an approach requires a sink rate greater than 1, 000 fpm, a special briefing should be conducted
- Thrust setting is appropriate for the airplane configuration
- All briefings and checklists have been conducted.

Note: An approach that becomes unstabilized below 1,000 ft AFE in IMC or below 500 ft AFE in VMC requires an immediate go-around."

2.1.24 At 0424:02 the Captain asked FO whether the runway was visible. The FO replied in negative and advised Captain to engage the autopilot, which could make runway contact easy. However the autopilot was not engaged.

2.1.25 At 0424:16 the cockpit crew reported their position to ATC Tower which was 04 DME runway 36L. The duty controller at ATC Tower replied ," recheck landing gears down & locked, wind calm, caution for birds and cleared to land runway 36L". The FO acknowledged by saying, "cleared to land when field in sight, Shaheen 142".

2.1.26 At 0424:32 the Captain continued to fly the aircraft and FO kept assisting him till they reached 500 ft AGL. The FO rechecked missed approach procedure and reset flight directors for a possible go around.

2.1.27 At 0425:24 when the system sounded "Five Hundred", the Captain once again asked FO whether runway was visible. The FO replied in negative. As the airplane was descending through 460 ft AGL, constant airspeed of 150 kts was maintained. The calculated airspeed for the weight of the aircraft at landing was 136 kts.

2.1.28 At 0425:41 the FO kept on guiding the captain to turn right, just before the system sounded "Minimums" the FO picked up visual with the runway towards right. The FO also took over the controls and asked Captain to inform ATC that runway was in sight. The aircraft temporarily levelled off at 400 ft AGL for approximately 7 seconds and simultaneously a right turn was initiated. While descending below 400 ft AGL, the vertical speed kept varying between -1100 ft/min to -180 ft/min. At 200 ft AGL, power was advanced to 55%-65% which increased airspeed and temporarily decreased sink rate. Although the FO picked up visual with the runway at Minimum Descend Altitude (MDA) by chance, however since the approach parameters in terms of "correct flight path" were not attained, a go around should have been initiated instead of efforts to align / land.

2.1.29 At 0425:47 the Captain also sighted the runway (at approximately 150ft AFE) and took over the controls from FO. However, the Captain was still unable to correctly align the aircraft with the runway, as the aircraft had ended up towards right side of the runway and a left turn was required. The FO was found asking the Captain to turn left but not only the Captain was unable to acknowledge the gravity of non normal situation he advised FO to 'relax'. The FO responded by saying "Ok...you had ended up well towards right of runway".

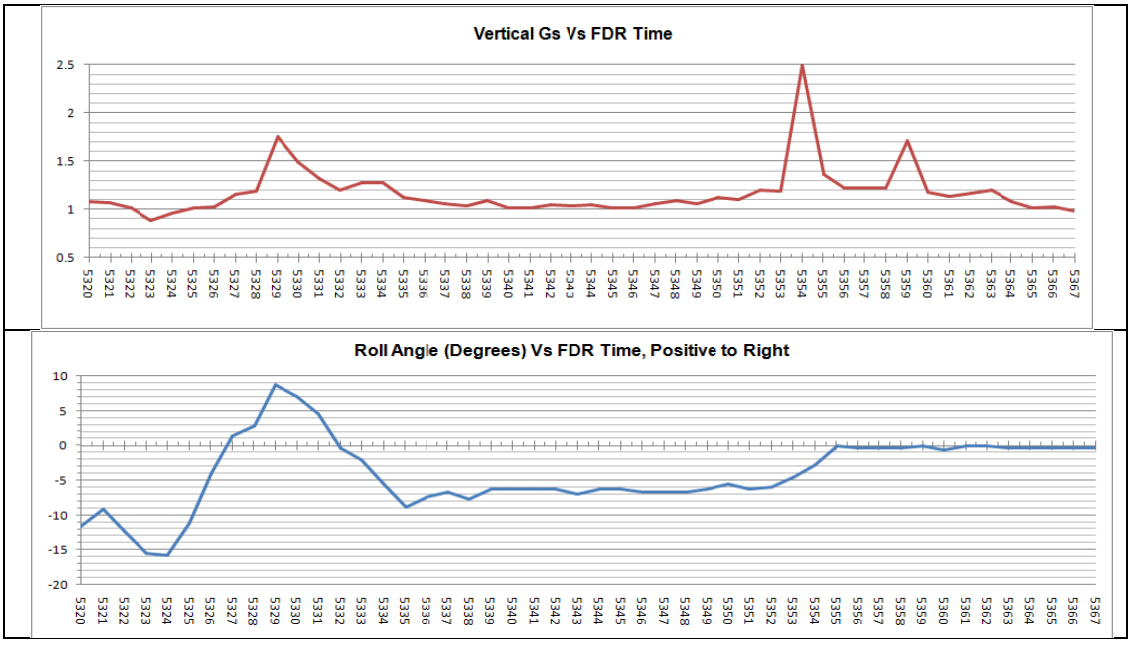
2.1.30 At 0426:07 soon after this the system sounded "One Hundred", FO made an effort to take over the controls from the captain in order to land the aircraft. The captain was heard uttering "Haye...Ok...Haye...Oh..." indicating total exhaustion and inability to cope up with the difficult situation. The Captain was unaware that he was still holding the controls despite handing over to FO. The FO was heard urging the Captain to leave the controls by saying, "Chorain...aap chorain...chorain..." {Leave it...you...Leave it...Leave it}. The Captain again voiced, "Haye...Oh". The FO was busy in landing the aircraft while Captain kept uttering exhausting voices besides being hyperventilated.

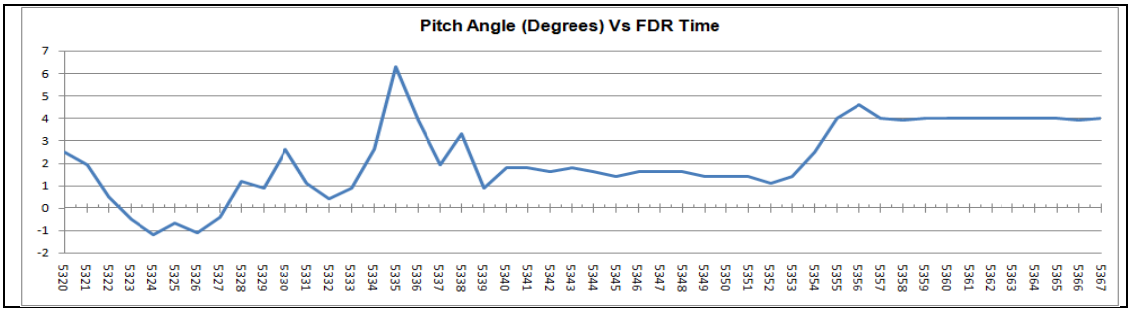
2.1.31 At 0426:13 the aircraft had reached its flare out height and system sounded “Fifty...Forty...Thirty...Twenty...Ten” and both throttles were retarded to idle. The aircraft touched down 1400 ft down form threshold lines in left half of the runway on right wheel in a right bank angle of 8°, a nose up attitude of 1.5° and 4.5° crab angle while the Captain and FO both were holding the controls and FO was making the landing. According to FDR data, the touchdown speed was 174 kts ground speed/166 kts True Airspeed against 134 kts of reference speed (Vref). Auto-speed brake got deployed at touchdown since it was armed. Thereafter, the aircraft slightly bounced and left wheel touched down the runway surface followed by second touching down of right wheel. When the left wheel touched down the left main landing gear broke following a shimmy event. Thrust reversers and brakes were applied, as speed brake was armed before landing.

2.1.32 The mishap aircraft departed runway towards left on fair weather strip due to high drag generated by rubbing of left engine cowling with the runway surface. Soon after MA departed the runway on soft ground, the right main gear also broke. The MA was now resting on both engines and nose wheel which remained intact throughout. The MA continued to skid on fair weather strip for 8000 ft before coming to final stop. Throughout landing roll the Captain and FO remained quiet and did not talk for any action till aircraft stopped. Thereafter since the captain did not ask FO for Engine shutdown checklist and evacuation of passengers. The same was accomplished by the FO. No passenger was injured during the incident or during emergency evacuation.

2.2. Technical Analysis

2.2.1 The initial landing contact of the aircraft with runway was indicated by the recorded local spike of 1.75 Gs in vertical acceleration at 5329.6 seconds FDR time. The FDR Ground speed, True airspeed were 174 kts and 166 kts respectively against reference speed of 134 kts at the time of touchdown. The roll angle at this time was about 8° to right side and pitch attitude was approximately 1.5° nose up. The RMLG outer tyre (No.4) marks started 1394 ft after the Runway Threshold and 28 ft towards the left of Runway Centerline (CL). The presence of No.4 tyre mark and FDR parameters of right roll and local spike in vertical acceleration suggested that this tyre mark was of the initial landing contact of the aircraft and corresponded with FDR time of 5329.6 seconds.





2.2.2 The FDR time of initial ground contact and corresponding ground mark was taken as reference. The forward distance covered by aircraft in each subsequent second was calculated using FDR recorded ground speed. The calculated forward distance was then used to estimate the FDR time corresponding to observed ground marks.

2.2.3 The LMLG tyre mark was noted at a distance of 2020 ft from RWT and 56 ft left of CL. The mark indicated that first the inner tyre (No. 2) contacted the ground and then outer tyre (No. 1) contacted after approximately 10 ft. Both tyre marks continued straight for about 30 ft and then became zigzag and gradually lightened in darkness (Para 1.12.3, Picture#10,11,12). Start of zigzag tyre mark pattern corresponds to FDR time of about 5332 seconds. It is pertinent to mention here that shimmy event excites the natural frequency of torsional oscillation of main landing gear inner cylinder inside the outer cylinder, which leaves characteristic zigzag tyre marks on the runway.

2.2.4 Some hard object (most probably LMLG wheel hub) mark was noted at 2434 ft from RWT, 49 ft left of CL indicating that most probably tyre deflated before this point (Para 1.12.3, Picture #10). The LMLG tyres most probably failed due to severe loading caused by sideways twisting and forward dragging and interaction with broken shimmy damper system links/ hardware. The presence of hub marks, presence of its broken pieces on the runway and damage to sides of the hubs and tyres also supported this assumption.

LMLG tyres

2.2.5 After hub mark very dark crisscross pattern of inner and outer tyres of LMLG started at a distance of about 2444 ft from RWT, 49 ft left of CL corresponding to approximate FDR time of 5333 seconds. The pattern continued for approximately 92 ft (Para 1.16, Picture #12). After failure of torsion link or shimmy damper actuator the sideways restraint ended and inner cylinder (attached to wheels axles) rotated inside the outer cylinder, as the aircraft was also moving forward. The torsional rotation of the LMLG tyre along with forward motion of aircraft left the crisscross tyres mark pattern.

2.2.6 The left engine cowling mark on the runway surface was located at 2650 ft from RWT, 56 ft left of CL (Para 1.12.3, Picture #13). This distance corresponds to FDR time of approximately 5334 seconds. The identification of the LMLG collapse time interval (5331 to 5335 seconds) was corroborated by increase in left roll and increasing of pitch angle.

2.2.7 The tyre marks indicate that LMLG did not immediately detach after collapse, rather it continued dragging along the aircraft leaving a typical tyre mark pattern alongside the engine cowling marks (Para 1.12.3, Picture #13). The pieces of LMLG tire, forward piece of upper torsion link, shimmy damper piston rod end and shimmy damper were located at 1362 ft, 3556 ft, 3818 ft and 4474 ft from RWT respectively. The LMLG was located on runway at 4540 ft from RWT.

2.2.8 Both brake pressure of over 2000 psi was commanded at approximately 5339 seconds and remained till 5351 seconds. Additional reverse thrust was also used on right engine. These inputs approximately correspond to 4100 to 7100 ft from RWT. Most probably after LMLG collapse aircraft started moving left and reverse thrust along with brake application was commanded to control the left movement. With the LMLG collapsed early in the rollout, braking on the left gear would have been ineffective thus leaving only the right brake as operative.

2.2.9 One piece of RMLG tyre (Para 1.12.3, Picture #14) was located on the path of the aircraft after it left the runway and was moving forward on unprepared surface. It appeared that tyre piece separated after it encountered a brick lining on the soft ground along the runway edge. The distance was 6996 ft from RWT and 10 ft away from runway left edge. Most probably the RMLG tyres failed due to cumulative effect of braking and encountering uneven load off the unprepared surface.

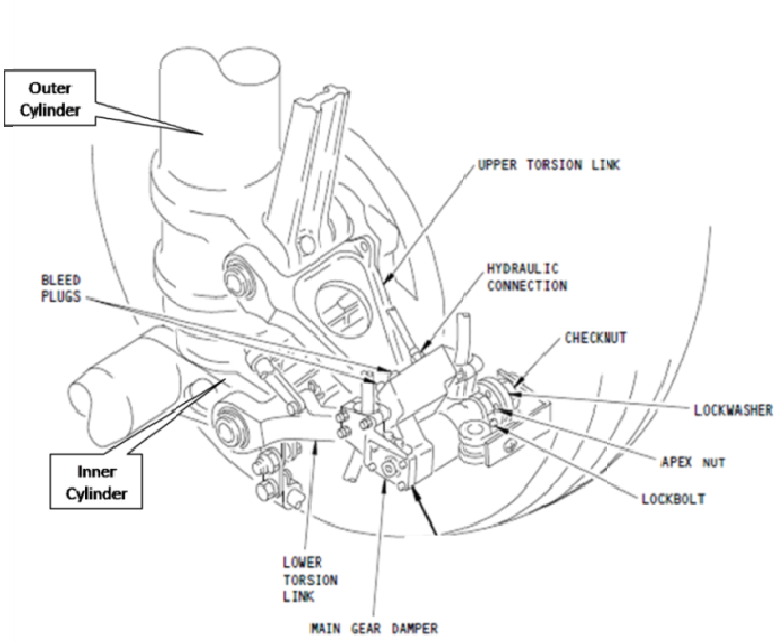
RMLG tyres

2.2.10 The FDR record shows that right roll angle decreased between 5352 to 5355 seconds, and then remained very close to zero degree. A local peak of vertical acceleration was also noted in this time interval. This time interval corresponds to RMLG collapse and is corroborated by ground contact of right engine cowling. The right engine cowling ground contact was evident by drag marks and presence of right engine cowling parts, miscellaneous hardware items and thrust reverser parts in the area centred at a distance of 7390 ft from RWT (Para 1.12.3, Picture #23). The RMLG was located at approximate distance of 7452 ft on the paved link from RWT along the aircraft path (Para 1.12.3, Picture #24).

2.2.11 After collapse of the RMLG the aircraft crossed the link and again entered unprepared area left of runway. It continued dragging on both engine and came to a stop at approximate distance of 8302 ft from RWT, 197 ft left of CL.

2.2.12 The RMLG closure rate at the time of its touchdown was 7.5 ft per second with a bank angle of about 8°. It is pertinent to mention here that closure rate was calculated by Boeing in their FDR report taking into account runway slope, pitch rate and roll rate and therefore, its value may differ from the recorded vertical speed. Boeing report evaluates this to be a hard landing on RMLG at approximately the design limit load level. Boeing report states that at this load level landing gear collapse would not be expected but an inspection would be warranted on the RMLG. The RMLG collapsed due to overload as the aircraft moved on unprepared surface with LMLG already collapsed.

2.2.13 The following pictures shows schematic of torsion links and shimmy damper assembly. 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 clearance/play at the attachment points of shimmy damper and torsion links are detrimental in effectiveness and efficiency of the whole mechanism to prevent torsional vibrations of the wheel assembly.



Torsion Links and Shimmy Damper Assembly

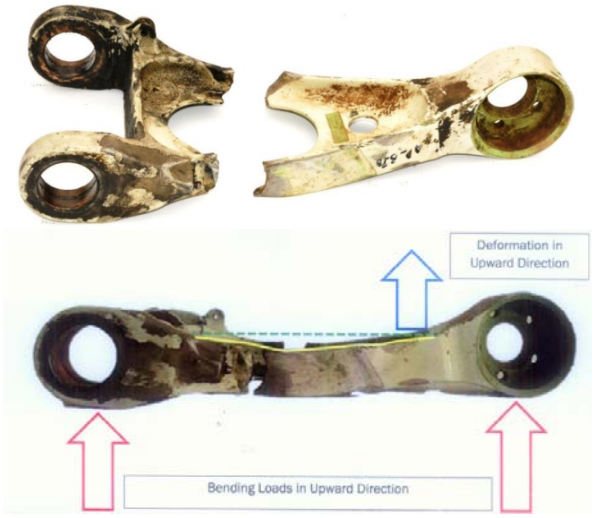
2.2.14 Ineffective shimmy damper mechanisms due to low sink rate, trapped air/internal leaks/failures of damper, and more than specified play of the associated linkages results in torsional vibrations, which is termed a shimmy event. If the vibrations approach the natural frequency of assembly then resonance 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 piston rod.

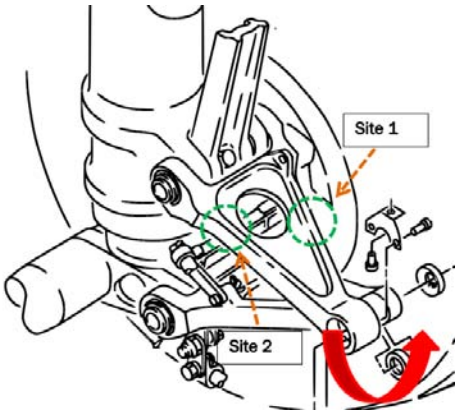
2.2.15 The LMLG touchdown mark corresponds to FDR time of 5332 seconds i.e. approximately 3 seconds after RMLG touchdown. The LMLG closure rate was approximately 1 foot per second with speed brakes deployed. The very low sink rate suggests that LMLG did not experience hard landing, therefore, the collapse of LMLG due to landing impact is ruled out. The tyre mark indicated that first the inner tyre (No. 2) contacted the ground and then outer tyre (No. 1) contacted after approximately 10 ft. The roll angle was increasing towards left side. This type of contact exerts torsional loads on the landing gear and may

excite torsional vibrations. It is pertinent to mention that low sink rate touchdown allows landing gear strut to remain in extended position for longer time. Shimmy damper torsion links have less mechanical advantage while the strut is in extended position and therefore, shimmy damping mechanism effectiveness to dampen the torsional vibrations is reduced. The information on the subject is also available in Boeing's publication Aero Quarter_03 13.

2.2.16 The failure mode analysis of the Upper Torsion Link (UTL) and Shimmy Damper Piston Rod (SDPR) was performed at Institute of Space Technology (IST), Failure Analysis Centre (FAC), Pakistan. The conclusions of FAC analysis reports are summarized below:

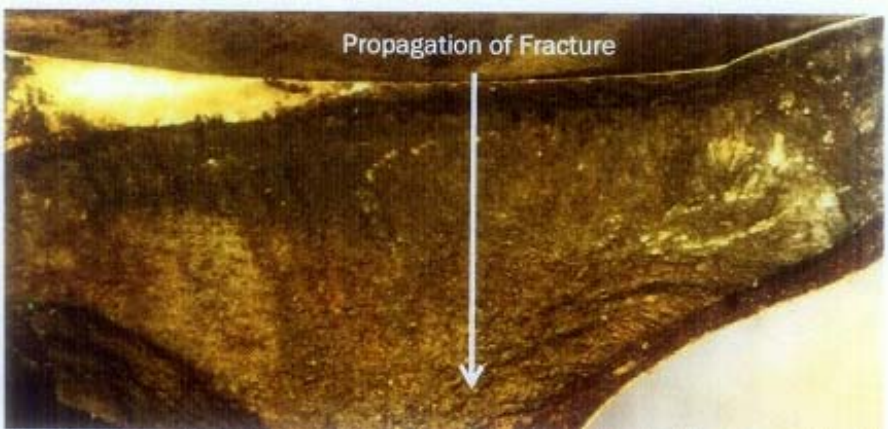
2.2.16.1 The UTL failed due to bending and torsional overload at locations marked site 1 and 2 as shown below. Both the sites exhibited identical deflection pattern, however site 2 exhibited deformations in multiple directions, indicating that bending forces on site 2 were not unidirectional. The bending overload caused the UTL to bend in upward direction as shown in picture below and site 1 breakage took place first. After breakage of site 1 the entire load transferred to site 2 resulting into its twisting, bending and breakage. The twist due to torsional load was evident on site 2.



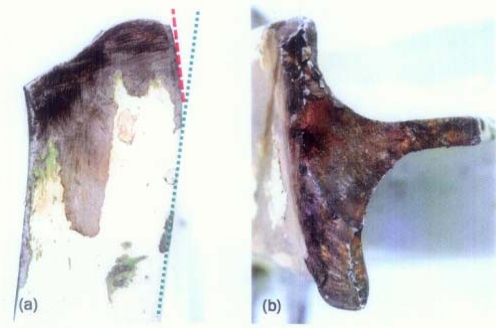


2.2.16.2 The fracture features at site 1 were completely destroyed due to secondary damage. The opposite fracture surfaces appeared to have interacted with each other, as their damage pattern was identical.

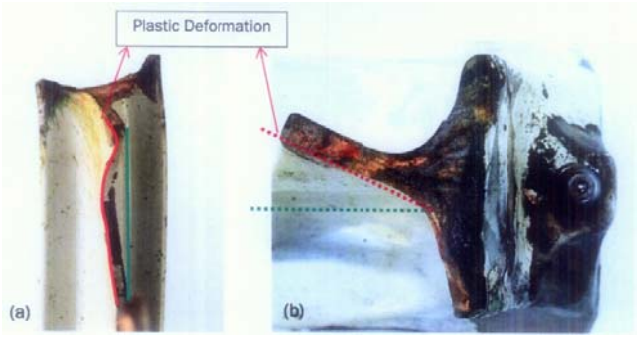
2.2.16.3 The fracture surface of site 2 contained radial marks, which were indicative of direction of propagation of fracture.



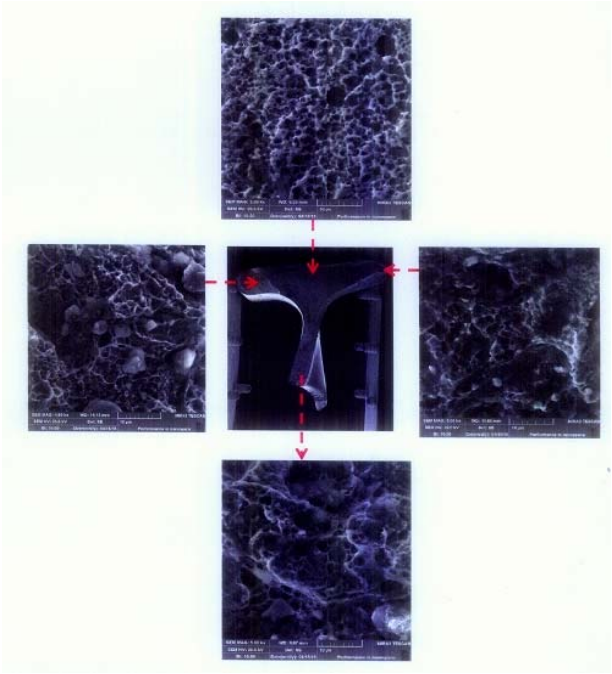
2.2.16.4 The visual examination of the UTL clearly indicated plastic deformation. The electron microscopy of fracture surface showed micro-void coalescence thus indicating a fracture due ductile overload.



Plastic deformation of site 1



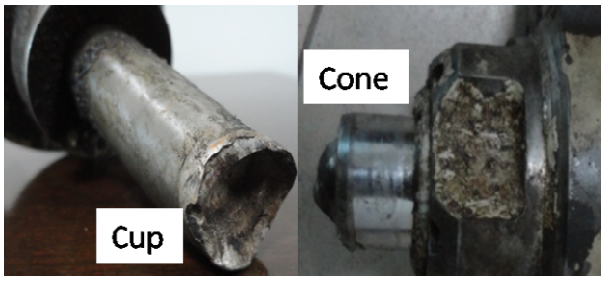
Plastic deformation of site 2
(a) Bending in multiple directions (b) Twist

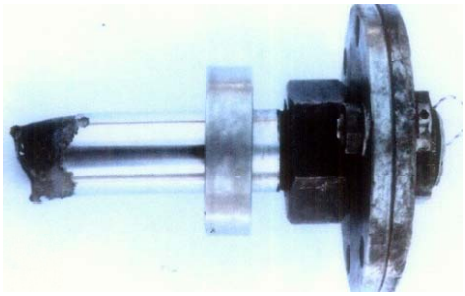


Micro-void Coalescence of UTL fracture surface

2.2.16.5 There was no evidence of fatigue, stress corrosion cracking and no deviation of chemical composition or microstructure of the material of the UTL.

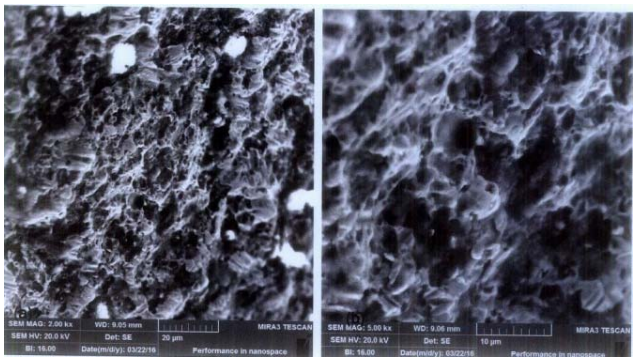
2.2.16.6 The failed Shimmy Damper Piston Rod (SDPR) exhibited plastic deformation and cup-cone fracture feature which is a typical of tensile overload failure in ductile materials.





Necking / Plastic Deformation

2.2.16.7 The electron microscopy of SDPR fracture surface showed micro-void coalescence on the thus further confirming the ductile overload failure. Secondary damage was also observed on the fracture surface.



Micro-void coalescence of SDPR fracture surface

2.2.16.8 The failure features of the SDPR correlated with ductile overload failure under tensile stress. The fracture appeared to have initiated from a key slot.

2.2.16.9 There was no evidence of fatigue or stress corrosion cracking. The chemical composition of the SDPR was in compliance with AMS 5643 (17-4 PH Stainless Steel). The microstructure of the part was observed to be normal.

2.2.16.10 The hardness value of the SDPR was less than the acceptable range for AMS 5643 (17-4 PH stainless steel) in H900 condition, The SDPR had Vickers Hardness Value (HV) of 343 as compared to 406-458 HV of AMS 5643 (17-4 PH stainless steel) in H900 condition. The Boeing comments vide 66-ZB-H200-ASI-186969 dated 06th February, 2017 stated that FAC performed hardness test was a micro-hardness check of very small area of the sample. Rockwell Hardness (HRC) or Brinell Hardness (HB) are bulk hardness measures. Since steel materials are not completely homogenous, a micro-hardness check, such as HV, may not give an accurate indication of all the overall tensile properties of the sample part. The hardness check also is dependent on proper surface preparation prior to testing to remove coatings or localize oxides. If proper surface preparation is not performed, it can lead to lower surface hardness indications.

2.2.17 The Boeing maintenance instructions in applicable Maintenance Planning Document (MPD) and Aircraft Maintenance Manual (AMM) specify inspection and adjustment of Shimmy Damper Linkages mostly in C-check. In order to address the problem of shimmy the Service Letter (SL 737-SL-32-057-D) dated 16th September, 2014 (applicable at the time of the incident) recommends more frequent checks, summarized as follows:

2.2.17.1 Adjust Main Landing Gear Torsion Link Apex Joint in accordance with AMM 32-11-81, Page 501, Main Landing Gear Damper Adjustment, starting at A-check and escalating incrementally up to every C-check or annually as service experience with the damper is attained.

2.2.17.2 After performing the above adjustment, measure across the faces of the thrust washers. If dimension is more than 2.7 inches, disassemble the joint and replace worn parts.

2.2.17.3 Disassemble the Apex Joint and inspect spherical cup washers, the damper piston, and the spherical bushings in the torsion link for wear annually escalating to every C-check as service experience with the damper is attained. Worn parts are to be replaced if measurable wear is detected.

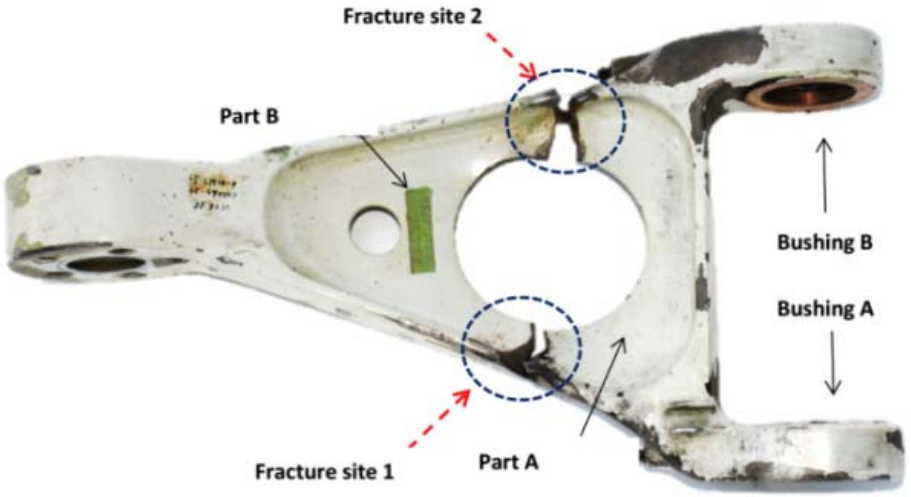
2.2.17.4 Bleed the air from the damper as per AMM 32-11-81, Page 401, Main Gear Damper Installation, annually, escalating incrementally up to every C-check as service experience with damper is attained.

2.2.18 The technical review of the Service Letter SL 737-SL-32-057-D was not performed by the operator prior to the incident and shimmy damper mechanism maintenance was being performed during Check-C as specified in AMM.

2.2.19 The assembled landing gear checks like “Torsion Links Apex Joint Check” with the help of a feeler gage and “Torsional Free Play Check” with the help of dial indicator in accordance with the applicable AMM are effective indicators of wear of the linkages of shimmy damper mechanism. Since the parts got damaged during the occurrence, therefore, these checks were not possible.

2.2.20 The measurement of wear of the bushing of torsional links and of corresponding lugs of inner and outer cylinder is an indirect method of ascertaining the condition of play of the assembled linkages of the shimmy damper system. More than specified wear of the bushings would invariably cause more than specified play in the assembled system.

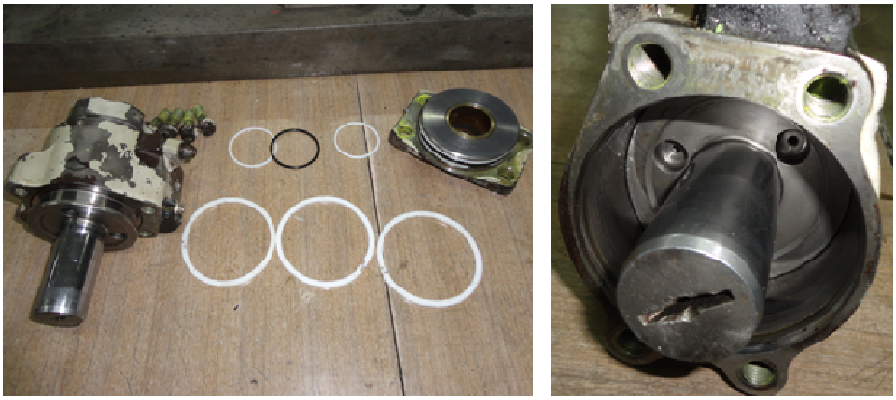
2.2.21 The dimensional check of the distance between the inner faces of the bushings of upper and lower torsion links of both main landing gears was carried out and found more than AMM specified wear limits (up to 6.394” as compared to maximum permitted 6.382“ as per AMM 32-11-51/603).



More than specified distance between bushings A and B results in excessive play in the assembly

2.2.22 It was possible that overload during shimmy event can compress the bushings. In order to verify the condition of shimmy damper linkages, One Time Check (OTC) was performed on three serviceable B737-400 aircraft of the operator for “Torsional Free Play”. The Torsional Free Play was found more than AMM specification on all three aircraft. The next check-C on these aircraft was falling due approximately within next 929 to 2392 hrs. The OTC findings supported the fact that operator’s maintenance schedule of inspection of shimmy damper and linkages during Check-C was not adequate, and there was a requirement of implementing enhanced frequency checks in light of recommendations of Boeing Service Letter SL 737-SL-32-057-D. The OTC finding also supports the assumption that wear of the bushings of the mishap aircraft was most probably present prior to the incident and was not solely result of overload during shimmy event.

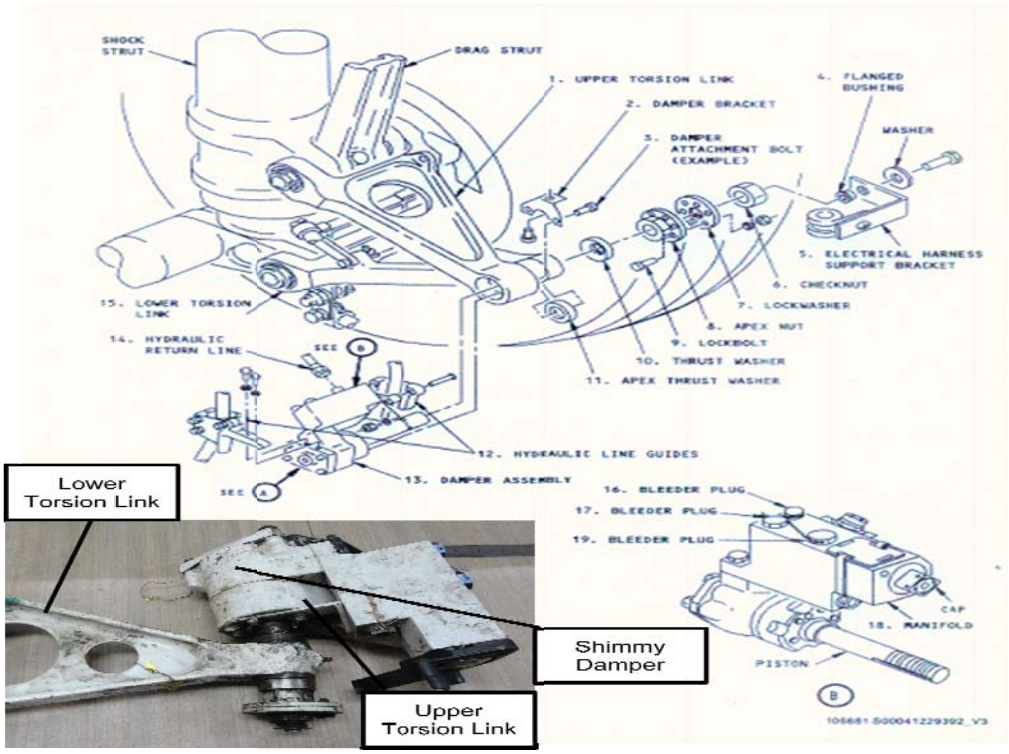
2.2.23 The internal hydraulic leaks/damaged of shimmy damper can also adversely affect the damping efficiency. The shimmy damper bench check was not possible because of damage to hydraulic ports and piston rod. The tear down examination was carried out and internal seals and piston was verified to be intact.



Shimmy damper internal seals and parts were found intact

2.2.24 The pitot static system of the aircraft was checked for leaks and no abnormality was discovered, thus ruling out the possibility of erroneous speed indication.

2.2.25 As discussed earlier, the forward piece of upper torsion link, outer piece of shimmy damper piston rod and shimmy damper were located at 3556 ft, 3818 ft and 4474 ft from RWT respectively. The forward link of the upper torsion link is attached to the shimmy damper body with the help of bolts. The shimmy damper piston rod passes through opening of the upper torsion link and is attached to the lower torsion link. The assembly sequence of the parts is shown in following schematic. The forward portion of the torsion link can dislodge only after breakage of its attaching bolts with shimmy damper body and breakage of the shimmy damper piston rod end. The evidence therefore, suggested that shimmy damper piston rod broke before separation of the forward portion of the upper torsion link from its assembly.



2.2.26 The tensile overload failure of the shimmy damper piston rod end suggested that it encountered overload due to large amplitude torsional vibrations during the shimmy event. The fact that there was no reported LMLG shimmy event prior to the incident and there was no evidence of fatigue failure of shimmy damper linkages suggests that the 15.5% reduction in strength of the shimmy damper rod was not responsible for failure under the normal circumstances. However, the occurrence of shimmy event introduced extra

ordinary load condition and the shimmy damper piston rod could not sustain it. After failure of the shimmy damper piston rod the inner cylinder was no more restrained against torsional movement inside the outer cylinder.

2.2.27 The upper torsion link most probably fractured after its interaction with adjacent parts (wheels, hubs, brakes and runway surface etc) whiles the aircraft was moving forward at high speed and LMLG wheels was no more restrained against torsional movement. The FAC report findings of failure due to bending and torsional overload of the upper torsion link also corroborate with the assumed sequence of events.

2.2.28 The runway marks (Para 1.12.3, Picture #10, 11, 12) and wheel wear pattern indicated that LMLG 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 tyres, upper attachment fittings and collapse of the landing gear.

2.3. Medical Analysis

2.3.1. After the accident, samples of blood and urine were collected from Captain and First Officer for laboratory investigation.

2.3.2. Alcohol and Lactate level of Captain were found 83 mg/dl and 70.0 mg/dl respectively in the laboratory investigation report. There were signs of Alcohol consumption (in the blood test) by the Captain prior to undertaking the mishap flight.

2.3.3. No alcohol was detected in the blood report of First Officer while Lactate level was 27 mg/dl.

2.3.4. Captain got initial Medical Certificate on 05th July, 1975. His medical record reveals Angiography and subsequently Angioplasty was carried out on 20 August, 2002 and 28 August, 2002 respectively. Cypher stents were placed in Right Coronary Artery and Left Circumflex Artery. He was declared temporary unfit by CAMB, Karachi on 15 July, 2002. Later on, he was declared fit for flying as or with qualified Co-Pilot on Multicrew Aircraft Operations by CAMB, Karachi dated 23rd June, 2003. Thereafter, he is flying with Operational Multicrew Limitations (OML). During CAMB dated 08th December, 2014, his random blood sugar level was reported 257 mg/dl, thus was declared to be a Diabetic. His subsequently investigations have shown well controlled diabetes with diet and exercise only. Last medical board of Captain was conducted on 29th June, 2015 which was valid up to 31st December, 2015. He had decreased near and distant vision for which he was advised to use corrective glasses.

2.3.5. First Officer got initial medical on 19th August, 2002 .The last medical assessment of First Officer was carried out by CAMB on 30th March, 2015 at Aero Medical Centre, HQCAA Karachi. His medical certificate is valid up to 31st March, 2016.

3. CONCLUSION

3.1 Operational Findings

3.1.1 The cockpit crew had valid licenses and medical fitness certificates; also they were authorized to undertake the flight.

3.1.2 The operator had provided sufficient rest to the cockpit crew before undertaking the flight.

3.1.3 The cockpit crew was adequately trained on B-737 aircraft and operationally fit to fly the aircraft on mishap day.

3.1.4 Before flight, when FO reached flight operations and received flight plan / weather information, the prevailing weather at AIIAP, Lahore and its surroundings was below the minima required to undertake mishap flight.

3.1.5 The mishap flight was a scheduled passenger flight from Karachi to Lahore. The scheduled departure time from Karachi was 0300 UTC and it was to arrive at Lahore at 0445 UTC.

3.1.6 The First Officer reported at Flight Operations 01 hour before whereas Captain arrived 45 minutes before scheduled departure time of the flight, whereas both were required to be in Flight Operations 01 hr 30 minutes before flight. The First Officer received Flight Plan, obtained latest weather information & NOTAMS. The METARs at different intervals during the period of flight indicated the visibility initially reducing trend to 1000 M. At the time of take off i.e. 0300 UTC from JIAP Karachi, the destination aerodrome had 1500 M visibility with misty outlook and increasing trend to 2000 M with 1500 M at the time of landing and increasing trend to 3000 M. This weather necessitated to delay the departure till visibility improved.

3.1.7 As per NOTAM, AIIAP, Lahore main runway 36R was not available due to ILS Cat-III up-gradation instead runway 36L was available for VOR DME approach. This was an important factor to be considered in prevailing weather for continuation of flight or otherwise. Due importance to this factor was not given and cockpit crew continued as per scheduled departure time.

3.1.8 The Captain conducted a short departure brief which included taxi route and Standard Instrument Departure (SID). The prevailing weather and forecast were neither discussed nor given due importance.

3.1.9 The Captain was Pilot Flying (PF) and First Officer was Pilot Monitoring (PM) for the flight.

3.1.10 According to Flight Plan the flight was to cruise at FL 330 and total flight time to destination was 1 hour 23 minutes. Only one alternate aerodrome was planned which was OPPS. The weather forecast at approximate landing time at OPPS indicated rain.

3.1.11 The Flight took off at 0308 UTC and carried out instrument departure as per brief. The flight climbed to its cruising altitude of FL330 as planned and remained uneventful during cruise. Before initiating descent as per flight plan, the cockpit crew obtained latest weather of destination aerodrome (OPLA) which mentioned visibility 1200 meters. This visibility was below the minimum required (1600m) for carrying out a VOR DME approach and necessitated decision for diversion to alternate aerodrome. The cockpit crew decided to continue for the destination. At this time the flight was with Karachi Area Control Centre (ACC).

3.1.12 Once the flight reached her planned top of descend (TOD), the cockpit crew completed descent checklist. It is worth mentioning here that the Captain and First Officer, during their approach brief, talked about landing through VOR DME approach on runway 36L but never considered RNAV approach.

3.1.13 After reaching planned TOD and Lahore Area Control Centre jurisdiction, the flight changed over to Lahore ACC frequency. Lahore ACC cleared the mishap flight for arrival to Lahore for VOR DME approach runway 36L. The Captain asked FO to request Lahore ACC for “ten miles finals runway 36R, initially” which was complied. Lahore ACC declined clearance for runway 36R and informed cockpit crew that the requested runway was not available due scheduled maintenance and also passed on latest weather as “ Lahore weather warning for poor visibility due mist up till 0700E and present visibility 1200 meters”. According to FO they were planning to follow ILS procedure for runway 36R with intention to break off after acquiring visual with the runway and landing at runway 36L. This was a non standard procedure.

3.1.14 Before changing over to Lahore Approach frequency, the FO asked Captain whether they had to go for RNAV. The Captain told him to request for RNAV approach for runway 36R. As the aircraft was not equipped with mandatory navigation equipment required for carrying out RNAV approach and the operator had also issued necessary instructions in this regard, also this decision was contrary to ICAO recommended procedure as per Doc 9613 para 3.4.1.1 and 3.4.1.2. At this stage, when the FO was cross checking the arrival procedure on Flight Management Guidance Computer (FMGC) he apprised the captain that by mistake the captain had selected runway 18L instead of runway 36L, which was later on accepted by the Captain and the FO was advised to change the arrival procedure. The conversation between Captain and FO at this time indicates that the Captain had difficulty in identifying / reading and feeding the correct arrival procedure due to loss of concentration.

3.1.15 The FO was continuously found to be prompting the Captain for decision making. In order to calculate RVR for VOR DME approach runway 36L, the FO calculated RVR as 1800 meters by multiplying visibility (1200m) with 1.5. He lacked the knowledge of RVR calculation procedure and did not consider availability of other services at runway 36L, like high intensity approach lighting system (HIALS) or high intensity runway lights (HIRL) as mentioned in Jeppesen General Airway Manual. Incorrect calculation of RVR was not corrected by the Captain as well.

3.1.16 As per criteria mentioned in above table, RVR was same (1200m) as the reported visibility due SALS 420M to lighting system installed on runway 36L. The required RVR for carrying out a VOR DME approach by Cat-C airplane at runway 36L of OPLA as per Jeppesen Chart 13-6 was 1600m.

3.1.17 When FO contacted Lahore Approach and informed that the flight was handed over to her and it was descending from FL 240 to FL150. Lahore Approach found the flight being right of track and inquired cockpit crew by asking them, if they were right of track. The Captain quickly asked FO to tell Lahore Approach that they were following RNAV procedure for runway 36L. The FO complied with the Captain's instructions. Lahore Approach acknowledged that and directed the FO to report position LEMOM while continuing descend to FL 70. Lahore approach acknowledged Captain's decision to follow RNAV and did not pursue for her previous clearance for VOR DME approach runway 36L and change of procedure to RNAV at this stage.

3.1.18 Lahore Approach cleared mishap flight for RNAV LEMOM ONE CHARLIE arrival runway36L, "descend down to 3000 ft on QNH 1018 hecta pascal and report position ELAMA". The FO acknowledged the approach by correctly reading back. The flight turned right from hdg 040^0 to 070° while descending through 10300 ft, with speed reducing through 273 kts and at a distance 27.4 NM from thresholds runway 36L.

3.1.19 The Lahore Approach observed the flight passing through FL85 at 20 track miles which was approx 2000-2500 ft higher than the assigned altitude. At this time, the cockpit crew selected Flaps-1, 2 and 5 in quick succession in order to increase the ROD, however speed brakes were not used. Lahore Approach contacted cockpit crew to reconfirm whether they will be able to make approach or will discontinue due to being high. The Captain immediately prompted FO to reply as "Affirmative". The FO replied as "affirmative, we can make it".

3.1.20 While flying from LEMOM to ELAMA the flight was neither following the track nor the assigned altitudes. The cockpit crew lacked desired situational awareness due to stress of poor visibility combined with loss of concentration of Captain probably due to effects of alcohol yet they wanted to continue for the landing at destination airport.

3.1.21 At this stage, the FO asked the Captain to use the Speed Brake so that the aircraft can quickly descend to desired altitude. The captain in response uttered exhaustive voice

indicating that he was unable to cope up with the difficult situation and required decision making due to incorrect aircraft parameters in initial landing phase combined with increased stress due to poor visibility.

3.1.22 In order to execute landing checklist, the Captain asked FO to lower Flaps-10 and lower Landing Gears. The FO complied with the instructions and confirmed. The Captain again voiced "haye...haye...haye". At this stage, they also lowered Flaps-15, Landing Light - On and Flaps-30. The Captain asked FO to complete landing checklist which was successfully done by the FO. By this time, the flight was approaching over ELAMA at 5400ft, 9.7 NM from thresholds runway 36L at speed approx 180 kts.

3.1.23 When the flight reported her position over ELAMA, Lahore Approach Control observed her to be at 5000 ft altitude instead of already cleared 3000 ft. The radar controller cautioned cockpit crew by telling them that their altitude at ELAMA should have been 3000 ft whereas he had observed it to be 5000 ft. He also advised them to continue at pilot's own responsibility; if they end up carrying out missed approach, they should continue to maintain runway heading and also advised to contact Tower. By these instructions, it appears that the Lahore Approach Controller was reasonably certain that the flight would end up carrying out missed approach.

3.1.24 After reaching over ELAMA, the flight turned left heading 355^0 and selected Flaps-30. The speed at this time was 180 kts and flight was descending through 5000 ft.

3.1.25 At 9 NM from RWT, the Captain disengaged the autopilot to lose excess height by increasing ROD and also executed turns to acquire the runway. However the captain's decision to disengage autopilot at this stage without being visual with the runway increased his workload. Resultantly, the aircraft descended with very high ROD from 2000-3500ft/min. The excessive ROD with Flaps-30 selected resulted in exceeding flap speed limit. The approach had become unstabilized and warranted a go around.

3.1.26 By the time the flight reached 4.6 NM from runway threshold lines, her parameters were hdg 356^0, Ht 1211ft, speed 170 kts and ROD 1300 ft/min which were almost correct at this distance from the runway but still not visual with the runway (the cockpit crew was actually carrying out VOR DME approach against their R/T communication of RNAV approach for which the aircraft was equipped). The Captain kept flying the aircraft with no visual cues due poor visibility, increased stress level, loss of situational awareness and reduced mental ability which led to ending up low on approach with high speed.

3.1.27 The Captain asked FO twice whether the runway was visible. The FO replied in negative and advised Captain to engage the autopilot, which could make runway contact easy. However the autopilot was not engaged.

3.1.28 At 04 DME short of runway when FO reported position to ATC Tower. , The controller replied to recheck landing gears down & locked, informed wind calm & caution for birds and cleared flight to land runway 36L. The FO acknowledged by saying, "cleared to land when filed in sight, Shaheen 142".

3.1.29 The Captain continued to fly the aircraft and FO kept assisting him till they reached 500 ft AGL. The FO rechecked missed approach procedure and reset flight directors for a possible go around.

3.1.30 When the system sounded "Five Hundred", the Captain once again asked FO whether runway was visible. The FO replied in negative. As the airplane was descending through 460 ft AGL, constant airspeed of 150 kts was maintained. The calculated airspeed for the weight of the aircraft at landing was 136 kts. The approach had become unstabilized due high speed and not being on correct flight path. This situation warranted an immediate go around.

3.1.31 The FO was guiding the captain to turn right without being visual with the runway and just before the system sounded “Minimums” the FO picked up visual with the runway towards right. The FO took over the controls and asked Captain to inform ATC that runway was in sight. The aircraft temporarily levelled off at 400 ft AGL for approximately 7 seconds simultaneously as a right turn was initiated. While descending below 400 ft AGL, the vertical speed kept varying between -1100 ft/min to -180 ft/min. At 200 ft AGL, power was advanced to 55%-65% which increased airspeed and temporarily decreased sink rate. Although the FO picked up visual with the runway at Minimum Descend Altitude (MDA) by chance, however since the approach parameters in terms of ”correct flight path” were not attained, a go around should have been initiated instead of efforts to align / landing.

3.1.32 When the Captain sighted the runway at approximately 150ft AFE, he took over the controls from FO. However, the Captain was still unable to correctly align the aircraft with the runway, as the aircraft had ended up towards right side of the runway and a left turn was required. The FO was heard asking the Captain to turn left but not only was the Captain unable to acknowledge the gravity of non normal situation he also advised FO to ‘relax’. The FO responded by saying “Ok... you had ended up well towards right of runway”.

3.1.33 Soon after this the system sounded “One Hundred” and simultaneously FO forcibly took over the controls in order to land the aircraft. The Captain was heard uttering “Haye...Ok...Haye...Oh...” indicating total exhaustion and inability to cope up with the difficult situation. The Captain was unaware that he was still holding the controls despite handing over to FO. The FO was heard urging the Captain to leave the controls by saying, “chorain...aap chorain...chorain” {Leave it...you...Leave it...Leave it}. The Captain again voiced, “Haye...Oh”. The FO was busy in landing the aircraft while Captain kept uttering exhaustive voices besides being hyperventilated.

3.1.34 The aircraft had reached its flare out height and system sounded “Fifty...Forty...Thirty...Twenty...Ten” and both throttles were retarded to idle. The aircraft touched down 1400 ft down from RWT in left half of the runway on right wheel in a right bank angle of 8°, a nose up attitude of 1.5° and 4.5° crab angle while the captain and FO both were holding the controls and FO was making the landing. According to FDR data, the touchdown speed was 174 kts ground speed/166 kts True Airspeed against 134 kts of reference speed (Vref). Auto-speed brake got deployed at touchdown since it was armed. Thereafter, the aircraft slightly bounced and left wheel touched down the runway surface followed by second touching down of right wheel. When the left wheel touched down the left main landing gear broke following a shimmy event. Thrust reversers and brakes were applied, as speed brake was armed before landing.

3.1.35 The mishap aircraft departed runway towards left on fair weather strip due to high drag generated by rubbing of left engine cowling with the runway surface. The right main gear also collapsed as the aircraft departed the runway on soft ground. The MA was now resting on both engines and nose wheel which remained intact throughout. The MA continued to skid on fair weather strip for approximately 8000 ft before coming to final stop.

3.1.36 Throughout landing roll the Captain and FO remained quiet and did not talk for any corrective action till aircraft stopped.

3.1.37 Since the captain did not ask FO for engine shutdown checklist and evacuation of passengers, the same was accomplished by the First Officer.

3.1.38 No passenger was injured during the incident or during emergency evacuation.

3.2 Technical Findings

3.2.1 The aircraft was serviced properly prior to the mishap flight and there was no carried forward defect which could contribute to the incident. The last one year maintenance history of the aircraft did not contain any recorded defect related to LMLG shimmy event.

3.2.2 The Shimmy Damper Piston Rod failed due to overload due to shimmy event with no evidence of fatigue.

3.2.3 The fracture surfaces of the Upper Torsion Link indicated a bending over load fracture with no evidence of fatigue or material deficiency. The upper torsion link most probably fractured after its interaction with adjacent parts (wheels, hubs, brakes and runway surface etc) whiles the aircraft was moving forward at high speed and LMLG wheels was no more restrained against torsional movement.

3.2.4 The shimmy damper internal mechanism was intact and there was no evidence of damage to its seals and piston.

3.2.5 The upper and lower torsion links of the mishap landing gear had more than specified wear of the bushings which created excessive play in the shimmy damper mechanism.

3.2.6 The RMLG experienced hard landing at approximately its design limit level. However, it did not collapse due to the initial hard landing. It collapsed due to overload while aircraft was moving on the unprepared surface.

3.2.7 The FDR Ground speed, True airspeed were 174 kts and 166 kts respectively against reference speed of 134 kts at the time of touchdown.

3.2.8 After the RMLG touchdown, the LMLG first inner tyre (No.2) and then outer tyre (No. 1) contacted the runway which provided torsional excitation.

3.2.9 The closure rate of LMLG during touchdown was approximately 1 foot per second. The low closure rate reduced the effective of shimmy damping mechanism.

3.2.10 The low sink rate touchdown and torsional excitation, in presence of play due to wear/deformation of the bushings of the torsion links created conditions conducive for violent shimmy of the LMLG.

3.2.11 The large amplitude torsional vibrations resulted into failure of LMLG Shimmy Damper Piston Rod and Upper Torsion Link. After failure of the torsion link and shimmy damper piston rod the LMLG wheels pivoted about strut axis and were not able to rotate with forward motion of aircraft, thus resulting in collapse of the LMLG.

3.2.12 Most probably the RMLG tyres failed due to cumulative effect of braking and encountering uneven load off the runway.

3.2.13 The RMLG collapsed due to overload as the aircraft moved on unprepared surface with LMLG already collapsed.

3.2.14 The operator’s maintenance schedule of inspection of shimmy damper and linkages during Check-C was not adequate, and there was a requirement of implementing enhanced frequency checks in light of recommendations of Boeing Service Letter SL 737-SL-32-057-D (Applicable at the time of incident).

3.3 Medical Findings

3.3.1 According to the laboratory investigation reports in respect of Captain, the blood alcohol level was 83 gm/dl. The impairment of Central Nervous System starts at 50 mg/dl or above that may result in judgmental errors as evident in this case. Moreover, the blood lactate

level of 70 gm/dl interprets fatigue due to increased stress as the normal level ranges from 4.5 to 23 mg/dl.

3.3.2 All the medical investigation reports in respect of First Officer are within normal limits except the blood lactate level (27 mg/dl) is slightly raised than the upper normal limit of 23 mg/dl which may be raised due to stress after the accident.

3.4 **Cause of Occurrence**. The accident took place due to:

3.4.1 Cockpit crew landing the aircraft through unstabilized approach (high ground speed and incorrect flight path).

3.4.2 Low sink rate of left main landing gear (LMLG) as it touched down and probable presence of (more than the specified limits) play in the linkages of shimmy damper mechanism. This situation led to torsional vibrations / breakage of shimmy damper after touchdown. The resultant torsional excitation experienced by the LMLG due to free pivoting of wheels (along vertical axis) caused collapse of LMLG.

3.4.3 The RMLG collapsed due to overload as the aircraft moved on unprepared surface.

4. OBSERVATIONS

4.1. M/s. Shaheen Air International did not verify the educational certificates of involved Captain as his Secondary School Certificate degree was declared bogus by Board of Secondary Education, Karachi. The verification of educational certificates was required as per Selection and Recruitment Policy of M/s SAI, para 6.

4.2. CAA Pakistan, as well as operator was not conducting random / snap tests for alcohol and psychoactive substances prior to this occurrence which was required to be done as per CAA Pakistan ANO-002-XXAM-1.0.

4.3. The airline doctor / flight surgeon of M/s SAI was found to be ineffective as none of the cockpit crew had consulted him for health issues in year 2015.

4.4. The disabled aircraft recovery equipment was not available at AIIAP, Lahore.

5. SAFETY RECOMMENDATIONS

5.1. **Operational**

5.1.1. M/s Shaheen Air International is to ensure implementation of Crew Reporting time as approved by Flight Standards Directorate in Shaheen Air International Operational Manual (Part A) Edition II Ch-7 p.10 para 7.7.

5.1.2. CAA Pakistan may study and issue clear policy providing guidelines on delaying departure or rescheduling of flights in case of marginal weather at departing / destination aerodrome keeping in view the trend of weather deterioration or improvement.

5.1.3. CAA Pakistan is to issue necessary instructions to all operators in Pakistan to emphasize their aircrew to read and understand NOTAMs in pre flight brief and utilize the information in NOTAMs in their flight planning.

5.1.4. All operators are to encourage their aircrew for in-flight decision of diversion to alternate aerodrome in case the planned destination aerodrome weather falls below the minimum required.

5.1.5. CAA Pakistan is to ensure that Alcohol / Drugs spot checks of all aircrew operating in Pakistan are carried out as mentioned in PCAA ANO-002-XXAM-1.0, which was not being done regularly prior to this occurrence.

5.1.6. All operators in Pakistan to advise their aircrew to mutually brief in detail any alternative procedure, especially landing, which may have become essential during flight under specific circumstances.

5.1.7. CAA Pakistan may carry out study and issue necessary instructions regarding disengagement of autopilot for correcting approach parameters. This aspect is to be viewed in conjunction with OEM recommended procedures and overall safety of aircraft.

5.1.8. CAA Pakistan is to issue necessary instructions to all operators to make their Airline Doctors / flight surgeons more effective. All sickness of aircrew must be reported to Airline Doctors / flight surgeons and proper record keeping is to be ensured in accordance with PCAA ANO-001-XXAM-2.0.

5.1.9. All operators to ensure implementation of their Selection and Recruitment Policy, especially verification of licences and educational / experience certificates, which was not followed during the induction of the Captain of Mishap Flight.

5.1.10. CAA Pakistan is to issue necessary instructions to all Boeing 737 operators in Pakistan to follow the landing technique given in Boeing Flight Crew Training Manual (FCTM), Chapter 6.

5.1.11. M/s Shaheen Air International is to ensure that the Captain and FO undergo CRM refresher training as lack of CRM in entire sequence of events is evident.

5.2. **Technical**

5.2.1 The operator (SAI) to perform One Time Check of “Torsion Links Apex Joint” and “Torsional Free Play Check” in accordance with the applicable Aircraft Maintenance Manual (AMM) and perform necessary adjustment/rectification as required. (This recommendation was implemented by operator during process of SIB investigation).

5.2.2 All operators of Boeing 737-100 / 200 / 300 / 400 / 500 (737 CL) Series, to conduct a review of Boeing Service Letter 737-SL-32-057E for implementation of the recommended enhanced frequency of maintenance on Shimmy Damper and associated linkages.

5.2.3 Civil Aviation Authority, Pakistan to review its existing airworthiness procedures to ensure that all operators perform necessary technical reviews of non mandatory manufacturer’s instructions/service letters, and implement required measures especially if they are facing problems in the area covered by the subject instructions/service letters.

5.2.4 All Boeing 737-400 operating cockpit crews may be briefed to adhere to Boeing recommended procedures & landing technique to ensure effectiveness of shimmy damper mechanism.