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الهيئة العامة للطيران المدني
UAE General Civil Aviation Authority

INCIDENT INVESTIGATION REPORT

General Civil Aviation Authority

Investigation and Regulation Section

Abu Dhabi, UAE

FINAL

AIRCRAFT INCIDENT REPORT

B737-800, VT-AXP
Sharjah Intl Airport
July 7th, 2009
United Arab Emirates

OBJECTIVE

This investigation is performed in accordance with the UAE Federal Act No 20/1991, promulgating the Civil Aviation Law, Chapter VII, Aircraft Accidents, Article 48, and in conformity to ICAO Annex 13 to the Chicago Convention.
The sole objective of this investigation is to prevent aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

INTRODUCTION

SYNOPSIS

On July 7th, 2009, at approximately 08:10 UTC, Sharjah airport, while the B737-800NG, registration VT-AXP aircraft operating the service to Trivandrum (India), was accelerating, the crew rejected the takeoff. The maximum speed reached was approximately 147 kt groundspeed,

According to the pilots statements, at IAS between 130-140 kt, the crew felt a vibration with a simultaneous drift to the left, the Pilot in Command (PIC) called for rejected takeoff procedure where the aircraft started to decelerate until it completely stopped.

When the Airport Fire Services reached the site, they found no signs of fire or smoke, as the PIC requested passengers to disembarked at the place where the aircraft stopped by utilising passengers' mobile airstairs.

The brakes of the main landing gears four wheels were seized due to high energy stop. In addition, the inboard left tyre was found damaged and lost a chunk that impacted the lower surface of the left hand inboard flap before settling down on the runway.

The Regulation & Investigation Section determined that the probable cause of the this Operators incident of rejecting the takeoff at high energy was the damage of the L/H INBD tyre which caused an abnormal takeoff roll felt by the PIC as a jerking motion. The cause behind the tyre damage was not determined.

The Regulation & Investigation Section recommends that:

- the Indian Civil Aviation Authority ensure that Operator adheres to its post incident self generated internal procedures of handling tyres installed at their fleet.
- the Air India Charters adhere to its post incident self generated internal procedures of handling tyres installed at their fleet.
- the UAE General Civil Aviation Authority enhance awareness of all the UAE B737-800 Operators of the incident and evaluate the necessity for the UAE Operators to enhance tyre inspections.

AIRCRAFT INCIDENT BRIEF

Operator/Flight Number: 536
Aircraft and Registration: B737-800NG, VT-AXP
Location: Runway 30 of Sharjah International Airport
Date: July 7th, 2009

The Investigation Team of the UAE General Civil Aviation Authority reached the aircraft after it had been towed to the Maintenance Area of Sharjah International Airport. The Team performed the necessary observations, photographed and sighted initial examination of the cockpit control switches status, emphasising on the Auto Brake and Anti Skid. The State of Registry (India) was notified according to the Standard Practices of ICAO Annex 13 paragraph 4.

Unless otherwise mentioned, time in this Report is Coordinated Universal Time (UTC). At the time of the incident the UTC was the Local Time of the United Arab Emirates minus four hours.

Notes:

1. The word "Aircraft" in this report implies the accident aircraft.
2. The word "Team" in this report implies the Accident Investigation Team.
3. The word "Operator" in this report implies the AOC holder of the accident aircraft.

ABBREVIATIONS AND DEFINITIONS USED IN THIS REPORT

AES	Airport Emergency Services
AMM	Aircraft Maintenance Manual
Assy	Assembly
ATC	Air Traffic Control
ATSB	Australian Transport Safety Bureau
DFDR	Digital Flight Data Recorder
F/O	First Officer
FOD	Foreign Object Damage
FWD	Forward
GCAA	General Civil Aviation Authority (UAE)
hrs	Hour(s)
IAS	Indicated Air Speed
ICAO	The International Civil Aviation Organisation
Investigation Team	GCAA/the Regulation and Investigation Team
kg	Kilogram(s)
km	Kilometre(s)
kt	Knot(s)
LG	Landing Gear
L/E	Leading Edge
L/H	Left Hand
LT	Local time of the United Arab Emirates
m	Metre(s)
MSN	Manufacturer serial number
MLG	Main Landing Gear
MTOW	Maximum Takeoff Weight
NLG	Nose Landing Gear
No.	Number
OUBD	Outboard
PIC	Pilot In Command
PPC	Pilot Proficiency Check
Psi	Pounds per Square Inch (Pressure Measurement Unit)
R/H	Right Hand
RPM	Revolution Per Minute
RTO	Rejected Takeoff
RWY	Runway
s	Second(s)
S/N	Serial Number
SOP	Standard Operating Procedures
SRM	Structure Repair Manual
T/R	Thrust Reverser
TWY	Taxiway
UAE	The United Arab Emirates
UTC	Coordinated Universal Time
V_1	Takeoff decision speed
V_R	Rotation speed

1. FACTUAL INFORMATION

1.1 History of the flight

On July 7th 2009, the B737-800NG, registration VT-AXP, with 172 passengers, 2 flight and 4 cabin crewmembers onboard, departed the gate in the Sharjah International Airport at approximately 0800 UTC to Trivandrum International Airport, South West of India.

The takeoff mass was 76,200 kg whereas the maximum takeoff mass of the aircraft was 77,100 kg, as indicated in the aircraft Certificate of Airworthiness.

The flight preparation was done normally and the aircraft was airworthy.

Engine No. 2 was started at approximately 0802:15, while engine No. 1 was started at 0803:03. The Aircraft started taxiing at approximately 0805:01. The Aircraft continued taxiing with the maximum recorded taxi speed of 17 kt. The Aircraft reached RWY 30 within four minutes. The DFDR indicates that the engines were running normally before entering the runway. The Aircraft lined-up on the runway approximately at 0809:01.

The Aircraft started rolling takeoff after entering the runway. At 0809:36 the ground speed was 147 kt and the airspeed indicating to be 149 kt. At that moment, the engines' power was reduced and then the Aircraft started to decelerate until it completely stopped.

During his interview, the PIC stated that during the takeoff roll, and between 130 to 140 kt, he felt a jerking motion, after which the aircraft veered slightly to the left. He called out in order to abort the takeoff. When the ground speed was approaching 147 kt, and at 0809:37, the auto brakes applied, the ground spoilers were fully extended at 0809:40 and thrust reversers were fully deployed at 0809:41.

The PIC attempted to steer the aircraft back to the centreline and kept doing so until the Aircraft came to a complete stop at 0809:57, he instructed the F/O to notify the Air Traffic Control Tower (ATC) about the rejected takeoff and requested fire service, he also instructed the cabin crew to remain seated.

The vehicles of the Airport's Fire Services arrived to the Aircraft within two minutes; the Tower Controller informed the PIC that no signs of fire or smoke were observed. At that time, the PIC, as he stated in his interview, elected to request an expedited passengers' disembarkation via mobile airstairs.

After the removal of the seized brakes, the aircraft was towed to the Airport Maintenance Area.

1.2 Injuries to persons

Injuries	Crew	Passengers	Total in Aircraft	Others
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	6	172	178	0
TOTAL	6	172	178	0

1.3 Damage to aircraft

An initial inspection on the Aircraft revealed that the four MLG brakes completely seized in weldment, the L/H INBD tyre found damaged and missing a chunk that impacted the lower surface of the L/H INBD flap after it department the tyre causing a dent at that area (see figure 7).

The remaining three tyres were eroded due to dynamic friction with the runway surface, but all were found inflated.

1.4 Other damage: None.

1.5 Personnel information

Pilot in Command

Date of birth:	19/01/1947
License number	ATPL UK/AT/211428C/A
License issuing State:	The United Kingdom
Date of initial issue	17/09/2004
Date of expiry	16/09/2009
Last route check	25/03/2009
Last proficiency check	25/06/2009
Medical certificate	Class 1, last check on 11/03/2009

First Officer

Date of birth:	17/09/1987
License number	CPL 5282
License issuing State:	India
Date of issue	04/06/2007
Date of expiry	03/06/2012
Last line check	01/06/2009
Last route check	10/03/2009
Medical certificate	Class I, Last check on 15/04/2009

1.6 Aircraft information

1.6.1 General Information

Manufacturer	Boeing
Type and model	B737-800NG
MSN	36328
Registration	VT-AXP
Certificate of Airworthiness	
Issuing Authority	Directorate General of Civil Aviation, India.
Issue date	05 February 2007
Valid till	13 February 2012

Certificate of Registration		
	Issuing Authority	Directorate General of Civil Aviation, India.
	Issue date	19 February 2007
Last maintenance check		
	Check	PH-15
	Date	22 May 2009
	Done at	6917:38 airframe hrs, 2728 cycles
	Next scheduled maintenance due at	7417:38 airframe hrs, 2928 cycles
Maximum certificated takeoff mass		77,110 kg
Maximum landing mass		66,360 kg
Engines		Two Turbofan, CFM56-7B27

1.6.2 The main wheels assy

No. 1 Main Wheel Assy P/N : 277A6000-204 S/N : B9524	No. 2 Main Wheel Assy P/N : 277A6000-204 S/N : B8273
No. 3 Main Wheel Assy P/N : 277A6000-204 S/N : B9113	No. 4 Main Wheel Assy P/N : 277A6000-204 S/N : B8913

1.6.3 The brakes assy

No. 1 Brake Assy P/N : 2612312-1 S/N : B4858	No. 2 Brake Assy P/N : 2612312-1 S/N : B4909
No. 3 Brake Assy P/N : 2612312-1 S/N : B6110	No. 4 Brake Assy P/N : 2612312-1 S/N : B4931

1.6.4 L/H INBD Wheel (No. 2) More Details:

- Main wheel S/N B8273
- Landings: 110
- Tyre S/N: 90785136, R0
- Tyre make: Goodyear
- Wheel Make: Honeywell
- Last shop visit: tyre change
- Last overhauled 29/10/07

1.6.4 Brake No. 2 More Details

- Brake S/N: B4909

- Make: Honeywell
- Last shop visit : routine stack change (second shop visit)
- Landings since new: 2941
- Landings since last shop visit: 706

1.7 Meteorological information

Actual weather at Sharjah International Airport on July 7th, 2009 at 0810 UTC: wind 150° 01 kt, visibility 7000 m, SKC (Scattered Clouds), temperature 38°C, and QNH 999 mb.

1.8 Aids to Navigation:

Not applicable .

1.9 Communications:

Not applicable .

1.10 Aerodrome Information

Takeoff runway	30.
Takeoff run available	4060 m.
Accelerate-Stop distance available	4060 m.
Landing distance available	3760 m
Width	45 m.
Magnetic variation	1.3°E.
Threshold elevations from sea level	116 ft
RWY slope	Variable at the whole length from 0.62% to 0.07%.
RWY pavement	Asphalt covering with 300 m. Concrete surfacing at the threshold.

There was no evident foreign object observed at the runway according to the runway inspection report that was completed at 0728.

1.11 Flight recorders

The Aircraft was equipped with one Cockpit Voice Recorder (CVR), and one Digital Flight Data Recorder (DFDR).

The accident aircraft's CVR and PCMCI Card of the DFDR were removed from the aircraft and were found in a good condition. The Investigation Team put the two recorders under his custody until they were shipped to the Operator's premises where they were opened and the data downloaded.

The identification plate of the accident aircraft's CVR and DFDR PCMCI Card showed the following information:

DFDR PCMCI Card

P/No. SS180Af12MB3000

S/No. IOD-SS-162

CVR

P/No. 980-6022-001

S/No. CVR120-03903

The review of the DFDR parameters explains the chronological sequence of the events as shown below.

DFDR Group	DFDR Item	Time	Event	Value	Comments
1	0-169		Aircraft heading at engine start	116.4º	
1	49	08:03:03	Engine 1 start	N1 2.3%	N1 more than zero
1	170	08:05:04	Start of taxi	115.7º	Clued by change of heading
1	170-358	08:05:04 to 08:08:12	Taxi period	99.1 º	Clued by change of heading
1	358	08:08:13	End of taxi	99.1º	Clued by change of heading
1	359-408	08:08:13 to 08:09:02	Turning to enter the runway	98.4 º to -57.7 º	Clued by change of heading
1	409	08:09:03	Aligning the runway 30	-58.7º	
1	410	08:09:04	Starting the takeoff roll	Approximately 18 kt	Ground speed started to increase
2	440-441	08:09:34 to 08:09:35	Power Levers retarded	101% down to 95%	N2 Decelerated
1	442	08:09:36	The aircraft started to decelerate	Longitudinal acceleration 0.179	Maximum Positive longitudinal acceleration Was reached and then started to convert
1	442	08:09:36	Maximum recorded airspeed	149 kt	In column H
3	443	08:09:37	Auto brakes applied	Column AF	From no brake it goes to AUTO BRAKE
1	443	08:09:37	Maximum recorded groundspeed	147 kt	In column I (each reading every 4 seconds)
4	444	08:09:38	Spoilers are not extended		
4	445	08:09:39	Spoilers in transit		
4	446	08:09:40	Spoilers fully extended		
7	446	08:09:40	Thrust reversers in transit		In columns D and after
7	447	08:09:41	The thrust reversers were deployed		
1	463	08:09:57	The aircraft became to a complete stop		Speed 0 in column I

1.12 Wreckage and impact information

The Aircraft came to a stop intact with the L/H INBD MLG wheel tyre lost a chunk.

1.13 Medical and pathological information:

Not investigated.

1.14 Fire

Not applicable.

1.15 Survival aspects

The Airport Fire Brigade and Emergency Services arrived within two minutes. Aircraft evacuation was carried out by disembarking the passengers via mobile airstairs provided by the Ground Handler.

None of the passengers nor crewmembers was injured.

1.16 Tests and researches

For the purpose of determining the functionality of the systems related to such an incident, the Investigation Team requested the manufacturers (Honeywell and Goodyear) for lab examinations of L/H INBD brake (no. 2) and the corresponding damaged tyre.

1.16.1 Tyre lab examination

In its tyre examination report, Goodyear listed the following observations (see figures 1 and 2 below):

- Remaining skid depth is 1 mm.
- Bead and sidewall: No noteworthy observations.
- Inner liner had no wrinkles.
- There is a large flat spot at 3 o'clock.

Figure 1- Tyre as received

Figure 2- Flat spot

1.16.2 Brake lab examination

Honeywell lab report no. DD/AIE 2009-001 which was prepared on Oct. 23, 2009 after the examination on brake No. 2 (P/N 2612312-1, S/N B4909) contained the following observations:

- *The piston housing was stamped with a manufactured date of March 2006. Based on AIE records, this brake had two shop visits prior to the aborted takeoff event.*
- *As removed from the box, running clearance was observed under each piston and wear pins were measured at 0.542 and 0.510 inch (unpressurized).*
- *Overall, the brake appeared to be in very good condition. Linings appeared to be sufficiently thick and no signs of displaced (delined) linings were observed. However, the rotors could not be rotated because of weldment.*
- *The brake was pressurized to 3000 psi. Wear pins were measured at 0.478 and 0.450 inch. At 3000 psi leaks were seen at three piston locations. On two pistons, fluid was observed on the outer diameter of the piston suggesting a leak path past the piston's outer diameter packing. The third piston showed only minor leakage which seemed to be internal to the piston suggesting the leakage may have been past the adjuster pin.*
- *Pressure was reduced to 150 psi and running clearance was measured at the various piston locations. All pistons had running clearance of 0.085 inch or greater as expected for a service worn brake.*
- *Brake pressure was reduced to zero and the piston housing was removed from the brake. The pressure plate linings were not welded to the 1st rotor and the backing plate linings were not welded to the 5th rotor. All lining surfaces between the 1st and 5th rotors were welded.*
- *Minor levels of lining transfer from the pressure and backing plate surfaces to the adjacent rotor surfaces was observed. This condition suggests that weldment of these surfaces also occurred but to a lesser extent. This condition is typical for steel brakes in that the backing plate and pressure plate surfaces tend to run cooler than heat sink components in the centre of the heat stack. No effort was made to pry apart the heat sink components that were welded.*
- *Remaining lining thickness measurements were obtained as follows: PP – 0.216 inch; S1 – 0.223 inch; S2 -0.178 inch; S3 - 0.200 inch; S4 - 0.158 inch; S5 0.185 inch; S6 – 0.160 inch; S7 – 0.167 inch; S8 – 0.145 inch; BP – 0.215 inch. Note: The lining positions that were welded were measured between the adjacent rotor and the steel stator plate surface. The thicknesses are as expected for a steel brake assembly. Based on wear pin remaining and the minimum lining thickness recorded, the minimum lining thickness at full wear pin use is expected to be approximately 0.100 inch.*

1.17 Organizational and management information:

The Operator is an airline authorized to operate by the Director General of Civil Aviation of the Indian Government with permit No S-14, first dated 22 April 2005, based in Mumbai, India and it is authorized to operate Scheduled Air Transport Services (Passenger and Cargo) with aircraft, under the legislation of the provisions of the Aircraft Act, 1934 and the Aircraft Rules, 1937.

1.18 Additional information:

1.18.1 Maintenance Performed

After the aircraft towed and parked at the Sharjah Airport Aircraft Maintenance Area, a special inspection and rectification according to the Aircraft Maintenance Manual, ATA Chapter 05, was carried out by the Operator's Maintenance. Operational check of brake/anti skid/auto brake system was carried out according to ATA 05, 05-51-07 "High energy stop/heat damage check" with no clues of malfunction of any of the checked systems. Then the aircraft was ferried back to Mumbai where final inspection and maintenance rectification were carried out.

Rectifications at Sharjah before ferrying the Aircraft to Mumbai were as follows, as per the Operator's maintenance entry:

- No. 1 wheel removed, high energy stop/RTO inspection accomplished as per AMM 05-51-07 for MLG No. 1 axle and found satisfactory
- No. 1 main wheel and brake assembly replaced per AMM
- No. 2 brake removed and high energy stop/RTO Inspection accomplished as per AMM 05-51-07 for No. 2 MLG axle and found satisfactory
- No. 3 main wheel and brake assembly replaced per AMM
- No. 3 brake removed and high energy stop/RTO Inspection accomplished as per AMM 05-51-07 for No. 3 MLG axle and found satisfactory
- No. 4 main wheel and brake assembly replaced per AMM
- No. 4 brake removed and high energy stop/RTO Inspection accomplished as per AMM 05-51-07 for No. 4 MLG axle and found satisfactory
- Since all brakes heat sink may have possibly melted and got welded due aborted take off at approximately 140 kt with full fuel/Pax MTOW 77 tons; brakes had to be removed for towing airplane away from runway.
- Hydraulic system B servicing done as per AMM
- Inspection of fuselage, external belly area, landing gear wheel well area, flaps. Stabilizer L/E, wing to body fairing carried out.
- Dent observed at L/H inboard aft flap at centre area, L=12" ,D=1/8", area cleaned/inspected, no delamination per SRM 57-53-02 fig. 103, sheet 05-05 and within limits
- Brake seizure condition inspection per AMM 05-51-15 done and found satisfactory.
- Operational check of auto brake system and antiskid system done per AMM and found satisfactory.
- CVR replaced per AMM and OPS test done
- PCMCI card replaced
- T/R deployed, checked and found satisfactory
- Engine run up done, taxiing check done, and Operation check of all flight controls and braking carried out by captain, found satisfactory.

The following rectifications were accomplished post Aircraft arrival to Mumbai,:

- High energy stop/Heat damage condition Inspection as per AMM 05-51-07
- Tyre tread loss/Tyre Burst inspection as per AMM 05-51-54
- Brake seizure inspection as per AMM 05-51-15
- Reinspection of work carried out at out station done.
- L/H inboard L/E aft flap repaired.

1.18.2 Tyre Snags

According to the Technical Logs, from the last 3 months until 1 week before the incident, nil snags were reported related to the brakes (see table below).

TECH LOG NO	DATE		SQUAWKS
	FROM	TO	
115	08/04/09	17/4/09	NIL SNAGS
116	17/4/09	22/4/09	
117	22/4/09	30/0409	
118	30/04/09	10/05/09	
119	10/05/09	17/05/09	
120	17/05/09	22/5/09	
121	22/05/09	30/05/09	
122	31/05/09	07/06/09	
123	08/06/09	13/06/09	
124	14/06/09	20/06/09	
125	20/06/09	28/06/09	

1.18.3 Tyres Pressure

The tyre pressure details of the Aircraft as shown below were obtained from the Operator Tyre Pressure Audit Form.

DATE	TYRE PRESSURE (PSI)						TYRE PR CHK (HOT/COLD)	SCHEDULE
	NW LH	NW RH	MW LH OB (#1)	MW LH IB (#2)	MW RH IB (#3)	MW LH OB (#4)		
20/6/09	205	205	205	205	205	205	COLD	TRANSIT
21/6/09	205	205	205	205	205	205	COLD	TRANSIT
21/6/09	205	205	205	205	205	205	COLD	EX.TRANSIT
23/6/09	205	205	205	205	205	205	COLD	TRANSIT
24/6/09	205	205	205	205	205	205	COLD	TRANSIT
26/6/09	205	205	205	205	205	205	COLD	EX.TRANSIT
27/6/09	200	205	205	200	200	205	COLD	EX.TRANSIT
28/6/09	205	205	205	205	205	205	COLD	TRANSIT
29/6/09	205	205	205	205	205	205	COLD	TRANSIT
30/6/09	205	205	205	200	200	205	COLD	EX.TRANSIT
01/7/09	205	205	205	205	205	205	COLD	TRANSIT
02/7/09	205	205	205	205	205	205	COLD	TRANSIT
03/7/09	205	205	205	205	205	205	COLD	TRANSIT
04/7/09	205	205	205	205	205	205	COLD	TRANSIT
06/7/09	205	205	205	200	205	205	COLD	TRANSIT
07/7/09	205	205	205	205	205	205	COLD	TRANSIT

From the data above, all tyre pressure of the L/H INBD Main wheel, in cold condition during the period between 20/06/2009 until 07/07/2009 of the sixteen flights, were 205 psi, except three times at 200 psi.

1.18.4 Brake Failures

Previous brake failures in Operator were experienced as given below.

No.	Brake S/N	Location	Removal Date	Landings Done	Remarks
1	B6222	#4 VT-AXF	4 Nov 08	801	Honeywell New brake
2	B6226	#2 VT-AXN	21 Sept 08	971	Honeywell New brake
3	B4789	#4 VT-AXF	10 Dec 08	770	Last Shop Visit from AI
4	B6224	#4 VT-AXN	30 Sept 08	1009	Honeywell New brake

1.18.5 Tyre Failures (De-capping)

Previous tyre failures in Operator were experienced as given below:

Reg.	Flt No.	Station	Sector	Wheel No.	Date	Retread No.	Landings Done
VT-AXB	IX 340	TRV	MCT-TRV	3	3/12/06	R2	91
VT-AXG	AI 424	MAA	KUL-MAA	2	18/5/07	R2	129
VT-AXR	IX 537	AUH	TRV-AUH	2	26/09/08	R3	179

1.18.6 Operator Consideration

On a post incident internal investigation report, the following information as well as maintenance rectification measures were explained by the Operator:

- That, as per industry, the No. 2 and 3 Main wheels are more affected than the other wheel locations. This is due to the fact that these tyres are more prone to the “Shoulder wear Problem “ (step wear) phenomenon that the industry is facing .
- That Boeing recommends to operate at higher inflation pressures and OPERATOR has since amended the tyre pressure audit form reflecting higher inflation.
- Notwithstanding these tyre de-capping incidents, it may be worth noting that as part of preventive measures, though main wheel tyres are approved for re-treading up to R-6 level, the Operator has for the time being, restricted the re-treading to R-4 level until further notice.
- On the Operator’s B737-800NG airplanes, the main landing gear wheel tyres, are to size : 44.5 X 16.5 -21 28 PR, and in respect of tyre shoulder wear, the following may be noted :
    - that as per information received from Boeing, many operators of 737-800 model airplanes have reported low tyre tread lives and high levels of tyre shoulder wear on the main gear tyres.
    - that shoulder wear, sometimes called "step" wear, is a condition where the outer tread ribs wear much faster than the inner tread ribs.
    - that many airlines have reported varying degrees of shoulder wear on 737NG main gear tyres manufactured by most or all of the approved suppliers.
    - that some operators have reported that the shoulder wear is worse on No. 2 and 3 wheel positions.

- The wear phenomenon is observed on many different airplane models and many different tyre sizes.
- Tyres that are designed to the "H" profile (such as the H44.5X16.5-21 tyre) seem to be affected more than type VII or radial tyres, although shoulder wear is sometimes seen on those tyre types as well.

- Prime factors controlling shoulder wear are :
  - Groove width
  - Groove placement
  - Carcass stiffness
  - Overall tread profile

  It is very difficult to achieve the correct balance of the above factors to control shoulder wear. It is generally felt that if the tyre suppliers can reduce the shoulder wear characteristic, then the overall tread lives will improve, since tyres will not be removed prematurely due to shoulder wear.
- Tyre suppliers acknowledge that tyre life is below expectation and are studying and/or implementing design changes intended to improve 737NG tyre life or reduce shoulder wear. In some cases, changes are being made to the retread processes since these can be implemented into service quicker than design changes to the carcass itself.
- The approved tyre suppliers (e.g. Dunlop, Goodyear, Michelin, Bridgestone) are making changes to their new and /or re-treaded tyres in an attempt to improve the tread wear pattern and the overall tread life.
- It is the considered opinion of aircraft manufacturer as well as the tyres vendors that at this stage, tyre design changes may be the only feasible way to reduce shoulder wear and increase tread life and as such there is very little airlines can do from an operational or a maintenance standpoint. However, below mentioned, changes have been considered by the Operator with a view to reduce the shoulder wear characteristics on main wheel tyres :
  1. Inflate tyres to the high end of the allowable range shown in AMM 12-15-51.
  2. Check tyre pressures daily to ensure that they are correctly inflated.
  3. Determine if the shoulder wear characteristic is occurring on new or retreaded tyres. Note that the wear characteristic may be different on new tyres versus retreads since the tread designs are not necessarily the same.
  4. Consider field evaluating another supplier's tyres to see if the wear characteristic or tread life is better under your operating conditions.
  5. Adhere to the tyre removal recommendations in the referenced service letter and in AMM 32-45-00.
  6. Avoid unusually sharp turns during taxi and towing operations.

1.18.7 Summarized Information on Developments by Tyre Vendors

Bridgestone Company :

- Bridgestone implemented a new tread compound across all of their tyre lines which has shown an improvement in tread life.
- Bridgestone has also developed an increased skid depth version of their H44.5X16.5-21 tyre.
- Bridgestone feels they have largely solved the shoulder wear problem on their 737NG tyres.

Dunlop Company :

- Dunlop made adjustments to their manufacturing processes that reduced premature tyre removals due to shoulder wear.
- Dunlop qualified a re-treaded tyre with deeper tread depth for improved life. Also, Dunlop is currently testing redesigned versions of their 737NG tyres.

Gooodyear Company :-

- Goodyear has been successful in reducing shoulder wear on 737NG main gear tyres.
- Goodyear will also be evaluating new tread compounds that are expected to increase tread life.
- Retread molds are being revised or replaced as rapidly as possible on a global basis to conform to the shapes and groove placements that have been found to help reduce shoulder wear.

Michelin Company :-

- Service evaluation of the new Michelin H43.5x16.0-21 tyre (P/N 029-892-0) is nearing completion.
- This tyre incorporates patented 'NBT' technology that has demonstrated notable tread life improvement in other applications.

Yokohama Company :-

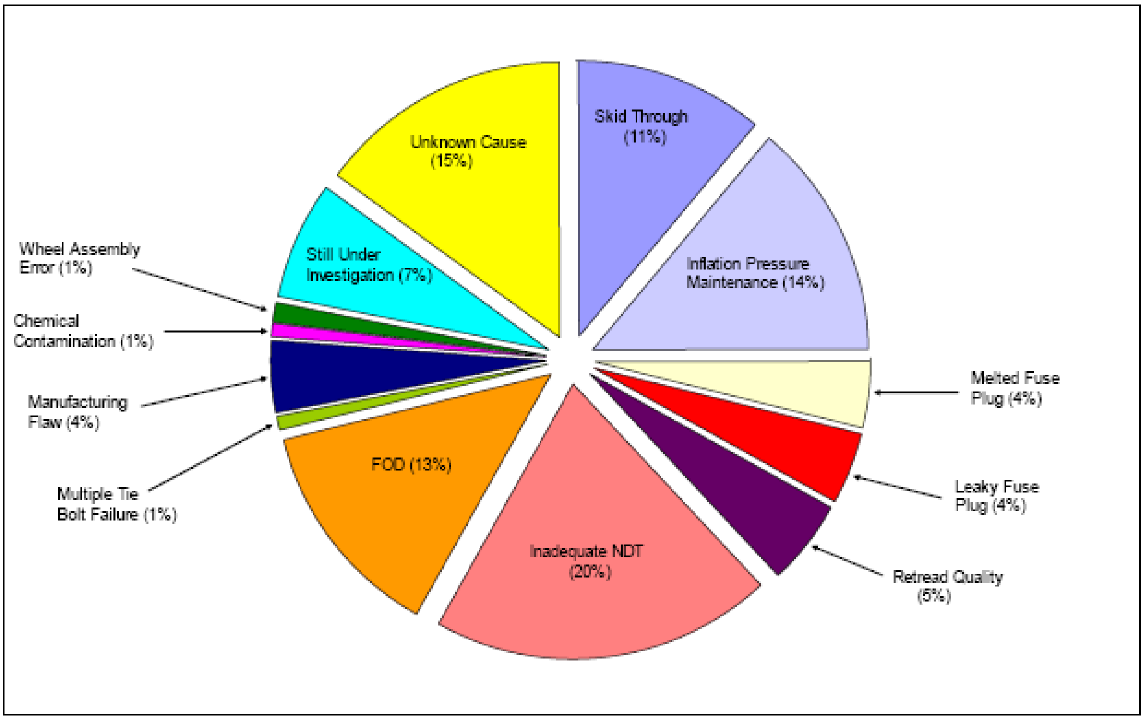
- Yokohama has recently introduced an H44.5X16.5-21 tyre into the 737NG market.

1.18.8 Summary of Boeing's 737 Tyre Failure Analysis, 2004 through 2006 (Refer to Attachment 3)

Figure 3 below shows a pie chart explaining the most known tyres failures causes as well as their percentage of occurrence.

DISTRIBUTION OF TIRE FAILURES BY CAUSE

As noted in a previous paragraph, Boeing attempted to assign a primary root cause to each tire failure. The results, as well as a detailed explanation of each root cause, are provided as follows. Note that ***Inadequate NDT*** of the tire during the retread process and ***Inflation Pressure Maintenance*** stand out as the prime root causes that are preventable.



"

DISTRIBUTION OF TIRE FAILURES BY ROOT CAUSE

Figure 3- Distribution of Tyre Failures by Cause (Quoted)

1.18.9 Boeing's Recommendations and Operator's Response

1.18.9.1 Recommendations by Boeing Manufacturers

Boeing has recommended the following based on their studies on tyres:

1. Inflate tyres to the high end of the allowable range shown in AMM 12-15-51. This reduces the sidewall deflection of the tyre and therefore reduces the heat generated by the tyre.
2. It is important to check tyre inflation pressures frequently.
3. If a tyre is identified as a leaker (as evidenced by two successive pressure checks where the pressure is more than 5% low), it should be removed from the airplane immediately. Note that tyres which are leaking gas though their inner-liner pose an imminent threat of a tread loss.
4. Operators should require that their retreaders perform the more complete bead-to-bead NDT checks (holography/shearography) on their tyres as opposed to just checking the crown area. This appears to be especially important on 737NG tyre sizes and is most critical when the tyres reach high retread levels. An example of a minimum NDT program might be as follows:

RETREAD LEVEL	INSPECTION*
R-0	Crown area (shoulder-to-shoulder)
R-1	Crown area (shoulder-to-shoulder)
R-2	Crown area (shoulder-to-shoulder)
R-3 and beyond	Crown and sidewall (bead-to-bead)

   * Using Shearography

   Notes (by Boeing):

   - The above NDT program is just a sample and should be adjusted based on individual operator's experience. Boeing Service Letter 737-SL-32-128 has been released on this subject.
   - For aircraft tyres, the term "retreading" refers to the methods of restoring a used retreadable tyre by renewing the tread alone or by renewing the tread plus the reinforcing ply(s) or protector ply.
     Full recapping is the recommended procedure for tyres with evenly worn tread, tyres with flat-spotted tread, or tyres with numerous cuts in the tread area. The new tread material extends around and over the shoulder of the tyre for several inches.
   - Retread Level (R-Level) Escalation is the process used to verify that a population of retreaded tyres is suitable for an additional service life.
5. There is a correlation between tyre failure and the retread level of the tyre. Several Operators affected by these tyre failures found that their tread losses only occurred on tyres at high retread levels. As a result, they elected to limit the number of times their tyres are retreaded

1.18.9.2 Operator's Comments on Boeing Recommendations

The Operator's post incident internal investigation report contains the following statements concerning the Operator's response to Boeing recommendations:

1. "Operator *has strict practice of inflating tyres every transit check, but not beyond 24 Hours elapsed time since last tyre servicing.*
2. *The tyre pressure gauges used by the Operator is calibrated every 3 months*
3. *The Tyre pressures are recorded in Tyre pressure audit form and is carried along with the Flight Log onboard the a/c. This enables all stations to peruse the record and take suitable action. Reached up to R4 and we scrap these tyre. In view of this Tyre decapping incident, we have decided to continue to limit the retread level to R4 for main wheel tyres, until further notice. and we earlier intimated all tyre retreaders, including our material planning division / Stores / QC etc*

4. *We had third case of Tyre de capping in the history of the Operator on our B737 a/c fleet & one case of tyre burst*
5. *Our understanding with tyre retreaders such a s Bridgestone / Goodyear is to have a "Bead to Bead " Shearography at all retread levels. This is ensure the integrity of the carcass as well as the tyre side wall condition etc.*
6. *This is a preliminary information & shall revert on further details."*

1.18.10 Main landing gear tyre failures of Australian operators of B737-800

During the investigation the Team searched for other tyre failure incidents. A statistical study conducted by the Australian Transport Safety Bureau (ATSB) was retrieved via the Internet.

The study revealed that since October 2004, there has been a series of Boeing 737-800 main landing gear tyre failures. Those failures involved:

- new generation high gross weight wheel tyres introduced into service approximately mid of 2002.
- tyres on either the fourth - R4 (one occurrence) or fifth - R5 (five occurrences) retread.

Retreading of aircraft tyres has been a proven practice for many years, and although failures have occurred from time to time, they are not a common event, with only four failures involving Boeing 737 aircraft reported to the ATSB during the period between January 2003 and October 2004. As such, the number of occurrences reported to the ATSB since 13 October 2004 represents a significant increase in occurrences of this type. The investigation of these tyre failures is continuing and is yet to determine the nature and mode of the failures, including any aspects relating to tyre manufacture, retreading, maintenance and operational considerations.

Summary of Boeing 737 tyre failures that occurred to Australian registered aircraft since October 2004 is shown below:

Date	Aircraft	Location	Model	Summary
13 Oct 2004	VH-VOJ	Brisbane Qld	737-81Q	The aircraft landed with a deflated right inboard main tyre. The tyre is thought to have deflated during the take-off run from Perth.
2 Dec 2004	VH-VOV	Sydney NSW	737-82R	During the take-off run from runway 01, damage occurred to one of the aircraft's main tyres and tyre tread debris was found on the runway. After landing in Sydney, the crew noticed that the right landing gear door had been damaged when the tyre tread separated.
3 Dec 2004	VH-VXF	Perth WA	737-838	Severely damaged tread found on main landing gear tyre during post flight maintenance.
4 Dec 2004	VH-VOH	Sydney NSW	737-86N	While the aircraft was taxiing for departure the crew heard and felt an unusual bump through the airframe. Shortly afterwards the Surface Movement Controller advised that the aircraft appeared to have a deflated main landing gear tyre. After inspection by ground personnel it was decided to taxi back to the terminal building, but during this manoeuvre the tyre began to shred. The aircraft was stopped on the taxiway and the passengers were disembarked for transport back to the terminal. Engineering staff replaced the both left main landing gear wheel assemblies and the aircraft

				was towed back to the parking area.
19 Dec 2004	VH-VOH	Canberra ACT	737-86N	During the landing, a main landing gear tyre blew, causing damage to the right landing gear doors, the right wing flaps and a hydraulic line in the landing gear bay.
20 Dec 2004	VH-VOR	Sydney NSW	737-8FE	After landing at Sydney, ground engineers noticed sidewall separation and shredding of the tyre shoulders on the left inboard main landing gear tyre.

In light of the industry experience in that period, the ATSB recommended that Australian Operators of Boeing 737-800 series aircraft review the practice of fitting retread tyres of R4 (fourth retread) or above, until their serviceability limitations can be identified.

On 23 December 2004, one of the Australian operators provided the following response to the mentioned above ATSB safety recommendation:

1. Amendments to its inspection methods to inspect the tyres more carefully on maintenance lay-overs and the pilots advised to scrutinise the main gear tyres during their pre flight inspections (needed at stations where transits are carried out without engineering involvement).
2. The maintenance practices on B737-800 aircraft require tyre pressure 'top ups' to be annotated in the aircraft Technical Log. Tyres requiring frequent 'top up' can be readily identified and action taken (progressive tyre deflation and repeated 'top up' is a good indicator of incipient tyre failure).
3. The Operator requires B737-800 tyres to be inflated to 208 psi after wheel assembly and left for 12 hours. The allowable pressure drop after 12 hours is +/-5 psi. This practice increases the chance of detecting a faulty tyre liner.

On 21 February 2005, another operator advised the ATSB that,: “in response to the subject safety recommendation, the Head of Engineering directed that the maximum retread level of all B737-800 main wheel tyres used in service would be the R3 level. This level conforms to the safety recommendation”.

1.19 Useful or effective investigation techniques

Not applicable.

2. ANALYSIS

The flight preparation was normal without any apparent problems and the aircraft departed the parking position of Sharjah International Airport after the ground handling process was successfully completed.

With the following parameters: Outside Air Temperature of 38 ºC, takeoff mass of 76, 200 kg and flaps setting at 5º (as the DFDR indicated), the Team calculated utilising the Boeing 737-800, Quick Reference Handbook, Takeoff Speeds, the V_1 to be 148 kt.

The aircraft taxied with a maximum recorded taxi speed of 17 kt.

Upon arriving to RWY 30, the crew initiated a rolling takeoff, i.e. they entered the runway without stopping and immediately advanced the engines’ power to start takeoff roll.

The aircraft started to accelerate at 08:09:04 from the speed of 12 kt then it continued accelerating until the groundspeed reached 147 kt at 0809:36. Assuming it was linear, the T/O acceleration could be calculated as:

$$\text{T/O acceleration} = \frac{(147\ kt - 12\ kt)}{32s^*} = 4.22\ kt/s.$$

* 32 s is the time from starting the acceleration and the maximum speed reached where the aircraft started deceleration (08:09:04 to 08:09:36).

Then the aircraft decelerated until it completely stopped at the runway during a period of 20s (from 0809:37 to 0809:57). Assuming that it was linear, the deceleration could be calculated as:

$$\text{Deceleration} = \frac{(0\ kt - 147\ kt)}{20s} = -8.71\ kt/s.$$

During his interview, the PIC stated that during the takeoff acceleration he felt a jerking motion followed by drift to the left of the centreline.

The first indication of rejecting the takeoff was the deceleration of the engines' rotations which happened at 145 kt. The decision to reject the takeoff and the subsequent actions were considered to be taken below the V_1 speed.

The examination of the L/H INBD tyre and the pertinent brake revealed that the tyre was found damaged and a chunk had disintegrated and impacted the lower surface of the L/H INBD flap centre before it finally settled at the runway.

The lab examination of the tyre showed an oval-shaped flat spot in the tread rubber extending through the casing. The report stated that *"An anti-skid malfunction or a locked brake is the most probable cause of this classic skid-through and casing break".*

In addition to that, the manufacturer's lab examination of brake No. 2 concluded that:

"1. Overall, the brake assembly appeared to be in very good condition following the reported aborted takeoff stop.
2. No specific root cause for the welded condition of the brake has been developed although this condition can occur after a high energy stop, such as an aborted takeoff, is performed.
3. Based on examination of the returned brake, no damaged or displaced parts are present. Moreover, all of the brake's adjuster mechanisms were verified to be functioning indicating that contact between the brake friction surfaces during runway acceleration would not have occurred assuming normal command of hydraulic pressure to the brake.
4. Brake linings were wearing in a typical pattern. Based on remaining wear pin and measured lining thicknesses, the brake assembly was not at risk for a deline event associated with overworn linings.
5. The rotor wear surfaces that mated with the PP and BP linings were in excellent condition and no indications of excessive gaps was observed between the rotor segments."

In its Summary, Honeywell lab examination report stated:

"….the brake was wearing in a typical pattern for a steel brake assembly. Moreover, as no linings were displaced, no damage was observed on the rotor assemblies, and the adjuster mechanisms were operational, the brake assembly was fully functional prior to the events that led to the welded condition."

The report added:

> *"For steel brakes, weldment of brake wear surfaces typically results from the following sequence:*
> *a. The brake assembly is heated significant enough to cause semi-molten lining material. Excess heating of the brake can result from excessive taxi applications, a dragging brake, inadequate cooling between landing sequences, or landing applications with improper flap settings, lack of thrust reverse, or high deceleration.*
> *b. Prior to sufficient cooling, park pressure is applied to the brakes and held.*
> *c. During the park period the brake cools and a weld bond is created between the stator linings and the rotor segments."*

As none of the four above mentioned issues were observed, before or during the incident flight, brakes weldment is mainly a result of excessive heat; however the sources of heat generation are variant. The only common thing amongst those causes is the contact of the stator lining and rotor segments for long time with insufficient cooling or high deceleration. But the fact that the wheels were being freely rolling during the takeoff roll would have cooled the brakes by airflow forced conviction. Therefore, a valid assumption could be that the temperature peak was reached at a moment earlier to the time of stopping the takeoff roll.

That assumption was supported by the summary of the brake's manufacturer lab examination report, the report stated that:

> *"The Operator has reported that the aborted takeoff was performed after some unusual noises were heard by their pilots during the acceleration takeoff roll. This description would suggest that free rotation of the brake rotors was occurring during the acceleration roll. Based on Honeywell experience, no known circumstance can lead to a welded brake when the airplane's wheels are in motion (taxi roll, takeoff roll, or a dynamic braking event)".*

Due to all of the above, the Team excluded the probability that the brakes had seized by weldment prior to the moment of the PIC decision to abort the takeoff.

In addition to that, the Team excluded the probability of inadvertent braking by malfunctioning brake/anti skid/auto brake systems since the results of the operational check that was carried out as a corrective maintenance and according to ATA 05, 05-51-07 didn't introduce any clue of malfunction on any of the checked systems (refer to 1.18 and Attachment 3).

The L/H INBD tyre (No. 2) was the only one amongst the four tyres which damaged and lost a chunk. The noticeable thing was that the width of the skid mark that was left by that tyre at RWY 30 was wider than the mating tyre (L/H OUBD, tyre No. 1), which indicated that tyre No. 2 was contacting the runway pavement with a surface wider than the normal tread width due to the addition of the tyre shoulders to its tread (compare between Dim. A and B in Figure 4 below). In other words, the tyre was skidding where it was completely deflated (see Figure 5 below).

Looking backward

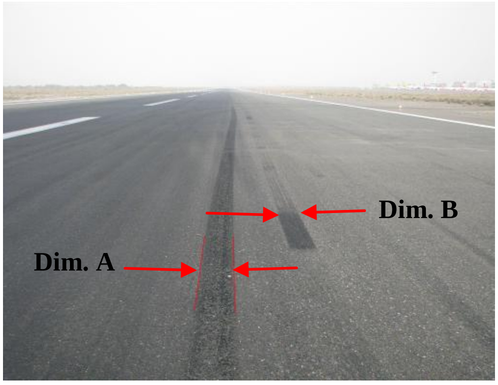


Figure 4- Width of the skid marks. Dim. A is the skid mark of the damaged wheel No. 2 tyre, B is the skid mark of wheel No. 1 tyre.

Figure 5- This portion of the tyre is the surface which made friction and caused the tyre skid mark (Dim. A in figure 3).

The deflation was a result of the tyre damage (see figure 5). The disintegrated chunk impacted the lower surface of the L/H INBD flap. The fusible plug which was intact and not melted indicated that the deflation was caused by the tyre damage and not by gas escape through the fusible plug.

In addition to the above those clues could be observed in figures 6 and 7 below.

The possibility that Tyre No. 2 damaged due to a Foreign Object at RWY 30 has to be excluded as the runway inspection report didn't indicate the existence of foreign object, on the takeoff runway prior to the incident.

Figure 6- the place of a dismantled chunk that hit the L/H INBD flap lower surface (see figure 6 to the right).

Figure 7- Lower surface of the L/H INBD flap shows a mark of the rubber chunk hit at high speed.

It is evident that various accident investigation authorities have contributed with extensive research after events involving tyres mainly of number 2 and 3. That's why all B737-800 operators should be aware and benefit from this research. The Operator has already amended its internal procedures. Nevertheless this change on their procedures should not lose the momentum. Furthermore, in case that other changes or amendments are required from other events from other operators, all other B737-800 operators should consider amending their internal procedures in order to minimise the possibility of such an occurrence. The incident Aircraft crew performed a high energy stop, that could be in other circumstances (limiting runway, obstacles, etc.) a catastrophic. In this Incident, the Crew and Aircraft performed as expected after the decision to abort the take off, as most probably the Crew did not feel that the aircraft was able to get airborne safely.

3. CONCLUSIONS

3.1 Findings

3.1.1 The flight preparation procedures were properly done.

3.1.2 The aircraft was airworthy and properly held valid documents.

3.1.3 The aircraft had a valid certificate of Insurance.

3.1.4 The flight crew properly held the appropriate licenses.

3.1.5 The taxi and takeoff were performed normally.

3.1.6 During the flight preparation, there were no indications of any anomalies in the aircraft engines or systems.

3.1.7 The flight crew felt a jerking motion during the takeoff roll and a rejected takeoff action was taken according to the applicable procedures.

3.1.8 There was no indication that the runway was a contributing factor to the incident.

3.1.9 FOD on the runway was not a contributing factor or probable cause of the incident.

3.1.10The tyres manufacturers have already taken action on events involving inboard tyres of B737-800.

3.1.11The Operator has generated post incident remedy internal procedures pertinent to handling tyres installed on their fleet.

3.2 PROBABLE CAUSE

The Regulation & Investigation Section determined that the probable cause of this incident of rejecting the takeoff at high energy was the damage of the L/H INBD tyre, which was felt by the PIC as a jerking motion. The cause behind the tyre damage was not determined.

4. RECOMMENDATIONS

The Investigation Department recommends that:

4.1 the Indian Civil Aviation Authority-

(a) **SR 05/2010**

ensure that Operator adheres to its post incident self generated internal procedures of handling tyres installed at their fleet.

4.2 the Operator-

(a) **SR 06/2010**

adhere to its post incident self generated internal procedures of handling tyres installed at their fleet.

4.1 the UAE General Civil Aviation Authority-

(a) **SR 07/2010**

enhance the awareness of all the UAE B737-800 operators of the incident.

(b) **SR 08/2010**

evaluate the necessity for the UAE Operators to enhance tyre inspections.

Final Report

Prepared by: The Investigation Department/GCAA