الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Serious Incident

- Final Report -

AAIS Case Nº: AIFN/0011/2016

Nose Gear Tire Tread Separation and Number 1 Engine Failure

Operator:	Etihad Airways
Make and Model:	Boeing 777-3FXER
Nationality and Registration:	The United Arab Emirates, A6-ETL
Place of Occurrence:	Abu Dhabi International Airport
State of Occurrence:	The United Arab Emirates
Date of Occurrence:	27 September 2016

Air Accident Investigation Sector
General Civil Aviation Authority
The United Arab Emirates

Serious Incident Brief

AAI Report No.	:	AIFN/0011/2016
Operator	:	Etihad Airways
Aircraft Type and Registration	:	Boeing 777-3FXER, A6-ETL
Number and Type of Engines	:	Two, General Electric, GE90-115B
Date and Time	:	27 September 2016, 1131 LT
Location	:	Abu Dhabi International Airport
Type of operation	:	Commercial, passenger
Persons On-board	:	352
Injuries	:	None

Investigation Objective

This Investigation was performed pursuant to the UAE *Federal Act No.20 of 1991*, promulgating the *Civil Aviation Law, Chapter VII - Aircraft Accidents*, Article 48; and in compliance with the UAE *Civil Aviation Regulations, Part VI, Chapter 3*; in conformity with *Annex 13 to the Convention on International Civil Aviation*; and in adherence to the *Air Accidents and Incidents Investigation Manual*.

The sole objective of this Investigation is to prevent reoccurrence of aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

Investigation Process

The Air Accident Investigation Sector (AAIS) of the United Arab Emirates was notified about the occurrence on 27 September 2016, at 1140 LT, by Etihad Airways Safety Department to the AAIS Duty Investigator (DI) hotline number +971506414667.

After an initial on-site investigation, the occurrence was classified as a 'Serious Incident'.

In accordance with the Standard Practice of *Annex 13 to the Convention on the International Civil Aviation*, an Investigation team was formed by the United Arab Emirates (UAE), being the State of Occurrence.

The International Civil Aviation Organization (ICAO), the State of Design and Manufacture (NTSB), and the Japan Transport Safety Board (JTSB), being the State of manufacture of the involved nose wheel tire (Bridgestone), were notified in line with the ICAO Annex 13 obligations. The AAIS conducted the Investigation and issued the Final Report.

This Final Report is publicly available at the link below:

http://www.gcaa.gov.ae/en/epublication/pages/investigationReport.aspx

Notes:

1. Whenever the following words are mentioned in this Report in Capital letter, they shall mean the following:
   - (Aircraft). The aircraft involved in this serious incident
   - (Investigation). The investigation into the circumstances of this serious incident
   - (Incident). This investigated serious incident
   - (Commander). The pilot-in-command of the incident flight
   - (Copilot). The copilot of the incident flight
   - (Report). This Final Report.
2. Unless otherwise mentioned, all times in this Report are local time of the United Arab Emirates, which is Universal Time Coordinated (UTC) plus 4 hours.
3. Photos and figures used in this Report are taken from different sources and are adjusted from the original for the sole purpose to improve the clarity of the Report. Modifications to images used in this Report are limited to cropping, magnification, file compression, or enhancement of color, brightness, contrast, or addition of text boxes, arrows or lines.

Abbreviations

AAIS	The Air Accident Investigation Sector of the United Arab Emirates
AEP	Airport emergency plan
AOC	Air operator certificate
ATC	Air traffic control
CAR	*Civil Aviation Regulations* of the United Arab Emirates
CCTV	Closed-circuit television
CSO	Cycles since overhaul
CVR	Cockpit voice recorder
DFDR	Digital flight data recorder
FAA	Federal Aviation Administration of the United States
FOD	Foreign object debris
GCAA	The General Civil Aviation Authority of the United Arab Emirates
ICAO	International Civil Aviation Organization
LH	Left hand
LT	UAE, local time
METAR	Meteorological terminal air report
MSN	Manufacturer serial number
PF	Pilot flying
PM	Pilot monitoring
RH	Right hand
TBL	Towbarless
TSO	Time since overhaul

Synopsis

On 27 September 2016, an Etihad Airways Boeing 777-3FXER, registration A6-ETL, was scheduled to operate a commercial passenger flight EY450 from Abu Dhabi International Airport (OMAA) to Kingsford Smith Airport (YSSY), Sydney, at approximately 1130 LT.

There were a total of 352 persons onboard, comprising 335 passengers, two flight crewmembers, two augmenting flight crewmembers, and 13 cabin crewmembers.

During takeoff, shortly after rotation, the flight crew heard a loud bang with associated No.1 engine high EGT, followed by a 'L ENG FAILURE' message on the Engine Indicating and Crew Alerting System (EICAS). The No.1 engine auto shut down. The takeoff continued and the flight crew trimmed and controlled the Aircraft and engaged the autopilot at approximately 400 feet above ground level (AGL). As the Aircraft rotated, the take-off distance was 2,920 meters and the remaining runway distance available was 1,180 meters.

Following the No.1 engine shutdown, the Commander declared a MAYDAY and decided to return to the departure airport. Air traffic control (ATC) acknowledged the MAYDAY declaration and the airport rescue and firefighting services were alerted.

ATC directed the runway safety team to inspect runway 13R and tire debris was discovered on the runway. The flight crew were advised of the debris by ATC.

The flight crew identified that the Aircraft had suffered a nose landing gear (NLG) problem, and they were uncertain as to the condition of the NLG.

The flight crew actioned the engine failure and the landing checklists, and the Aircraft landed safely at 1203:44 LT.

The airport rescue and firefighting services attended the Aircraft on the runway immediately after landing, and the Commander was informed that there were no signs of fire. The passengers and crewmembers disembarked using two passenger stairs positioned at the R1 and R2 doors.

There were no injuries to persons as a result of this Incident.

The Air Accident Investigation Sector (AAIS) determines the causes of the Incident were the shedding of the No.1 nose wheel tire tread as a result of contact with FOD. Subsequently, No.1 nose wheel tire debris was ingested by the No.1 engine causing its failure.

A total of six safety recommendations are included in this Report. The safety recommendations are addressed to the General Civil Aviation Authority of the United Arab Emirates (GCAA), Abu Dhabi International Airport, and the Federal Aviation Administration of the United States (FAA).

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1. Factual Information

1.1 History of the Flight

On 27 September 2016, an Etihad Airways Boeing 777- 3FXER, registration A6-ETL, was scheduled to operate a commercial passenger flight EY450, from Abu Dhabi International Airport (OMAA), to Kingsford Smith Airport (YSSY), Sydney, with a departure time of 1130 LT. During takeoff, the No.1 engine failed and the Aircraft subsequently returned to the departure airport.

There were a total of 352 persons onboard, comprising 335 passengers, two flight crew, two augmenting flight crew, and 13 cabin crewmembers.

The Commander, who was the pilot flying (PF), was seated in the left seat, and the Copilot who was the pilot monitoring (PM) was seated in the right seat. For the takeoff from Abu Dhabi, two augmenting pilots were seated in the cockpit observer seats.

The crew had obtained the weather information indicating that there was clear visibility and a temperature of 36 °C.

The calculated take-off weight was 347,807 kg, with a V_1 speed of 174 kt and V_R of 181 kt.

The Aircraft was parked at parking bay 308. The pushback was conducted using a conventional tug and towbar combination. After pushback at 1120 LT, the Aircraft taxied to runway 13R (figure1), along taxiway Echo 6, crossed runway 13, turned left onto taxiway Delta, then turned left onto taxiway Delta 2 to enter runway 13R.

During takeoff, at 1130:36 LT, the temperature was 36 ˚C. As the Aircraft accelerated towards V_R, the flight crew felt vibration in the cockpit. At rotation, 54 seconds after the take-off roll commenced, with an indicated air speed (IAS) of 196 kt, a loud bang was heard. This was followed by a “L ENG FAILURE” message on the engine indicating and crew alerting system (EICAS) display, with an associated high No.1 engine exhaust gas temperature (EGT). The indicated engine vibration recorded on the flight data recorder showed an increase from below ‘1’ unit to ‘5’ units, and the N_1 indicated rotational speed per minute (rpm) dropped suddenly from 102.4 to below 31.8.

The No.1 engine auto shut down at 1131:32 LT. The takeoff continued and the flight crew trimmed and controlled the Aircraft and engaged the autopilot at approximately 400 feet above ground level (AGL). As the Aircraft rotated, the take-off distance was 2,920 meters and the remaining runway distance available was 1,180 meters.

The Commander continued the climb on the No.2 engine. The IAS dropped to 172 kt as the Aircraft climbed to a radio altitude of 369 ft. The landing gear lever was selected to the ‘up’ position at a radio altitude of 539 ft and IAS of 182 kt. The flight crew completed the engine failure checklist at 1132:58 LT.

Following the No.1 engine shutdown, the Commander discussed the situation with the Copilot and with the augmenting flight crew. He declared a MAYDAY at 1134:51 LT, which was acknowledged by Abu Dhabi air traffic control (ATC).

ATC alerted the airport rescue and firefighting services, and directed the runway safety team to inspect the departure runway 13R. The inspection resulted in tire debris being discovered on the runway. The flight crew were advised of the debris by ATC.

The flight crew identified that the Aircraft had suffered a nose landing gear (NLG) problem and they were uncertain as to the condition of the NLG.

ATC advised the crew of the option to fly pass the control tower to allow a visual inspection of the NLG. The Commander declined this option and elected to continue the climb and maintain an altitude of 1,000 ft.

The flap lever was moved to position 5 at an IAS of 206 kt and a radio altitude of 1,475 ft. Subsequently, the Aircraft climbed to 4,000 ft.

In preparation for a single engine overweight landing on runway 13L, an approach speed of 201 kt (V_{REF20} + 5) was selected and the autobrake set to position 4.

The Aircraft touched down at 1205:14 LT, at an IAS of 192 kt, approximately 1,280 meters beyond the threshold, and came to a complete stop after travelling 2,590 meters. The runway remaining distance was 230 meters (figure 2).

The Aircraft landed at a calculated weight of 341,481 kg. The total flight time was 33 minutes and 41 seconds.

The airport rescue and firefighting services attended the Aircraft immediately after landing, and the Commander was informed that there were no signs of fire. The passengers and crewmembers disembarked on the runway using two passenger stairs positioned at R1 and R2 doors.

As the Aircraft was overweight, the rollout after landing was prolonged causing high brake temperatures. The Aircraft main landing gear (MLG) thermal fuses melted due to the high brake temperatures, and all of the MLG tires deflated (figure 3). Due to the deflated MLG tires, the Aircraft remained stationary on the runway. Both nose gear tires maintained their pressure. The No.1 nose wheel tire had shed its tread. (Figure 4).

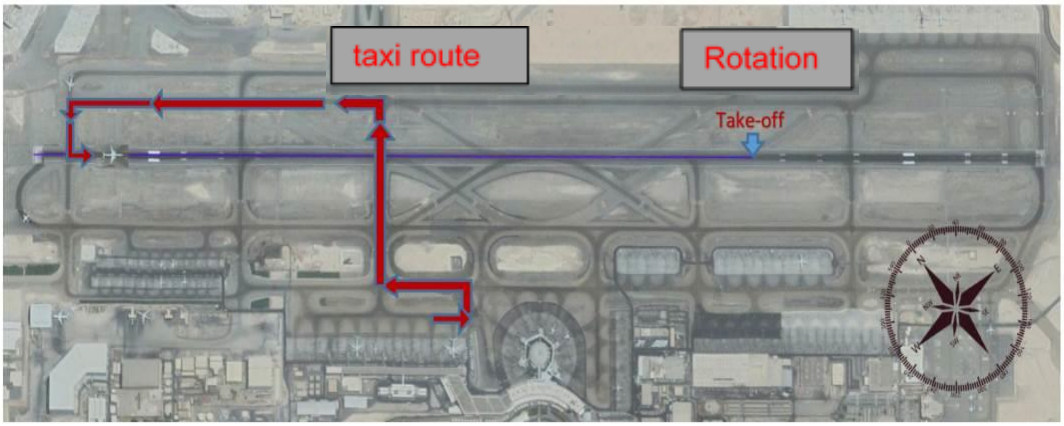

Figure 1. EY450 taxi route to runway 13R

Figure 2. EY450 landing on runway 13L

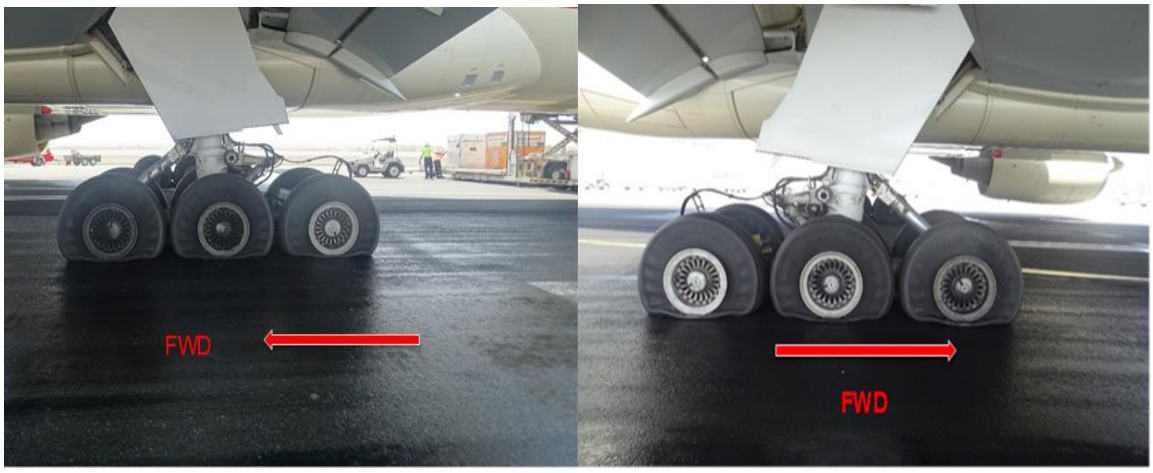

Figure 3. MLG wheels (LH & RH) deflated

Figure 4. No.1 nose wheel tire and steering cable damage

1.2 Injuries to Persons

There were no injuries to persons because of this Incident.

Table 1. Injuries to persons

Injuries	Flight Crew	Cabin crew	Other crew	Passengers	Total onboard	Others
Fatal	0	0	0	0	0	0
Serious	0	0	0	0	0	0
Minor	0	0	0	0	0	0
None	2	13	2	335	352	0
Total	2	13	2	335	352	0

1.3 Damage to the Aircraft

The Aircraft suffered damage to the lower fuselage, aft of the NLG bay (figure 5). The No.1 engine fan blades and engine inlet sustained damage (figure 6) and the nose gear steering cable was damaged (figure 4). In addition, there was evidence of tire debris impact on the inboard fan cowling of the No.2 engine.

More than 90% of the outer layer of the No.1 nose wheel tire tread had separated and disintegrated (figure 4). Following the landing, all of the main gear tires were found to be deflated (figures 3). The nose wheel tires remained inflated. There was no damage to the main gear wheel hubs.

Figure 5. Damage to lower fuselage aft of the NLG bay

Figure 6. LH engine fan blades and Inlet damage

On separation of the No.1 nose wheel tire tread, the tread broke up and pieces impacted several areas of the Aircraft. Tire debris struck the lower fuselage aft of the NLG bay, the No.1 engine, and the inboard fan cowling of the No.2 engine (figure 7).

The No.1 engine suffered foreign object damage (FOD), following ingestion of liberated tread which subsequently caused an uncommanded in-flight shutdown (IFSD) shortly after takeoff.

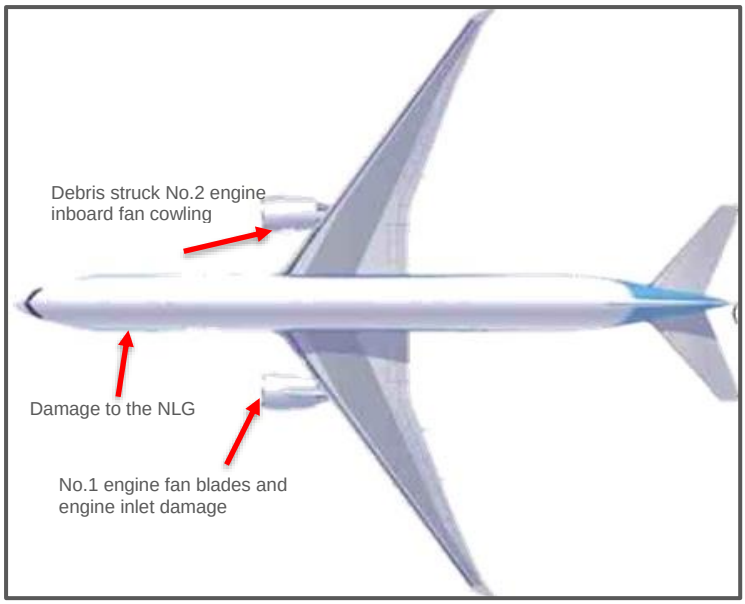

Figure 7. Locations of damages resulting from the No.1 nose wheel tire tread separation

The No.2 engine inboard fan cowling was struck by tire debris, but the cowling was not damaged. No tire debris was ingested by the No.2 engine.

1.4 Other Damage

There was no other damage to property and/or the environment.

1.5 Personnel Information

1.5.1 The Commander

The Commander's was 39 years old, and held an Airline Transport Pilot Rating M/E LAND A320, A330 (P2) Boeing 777/787, valid until 8 October 2021, with 8,130 total flying hours, including 1,325 total hours on the Boeing 777. The Commander passed all training required by the Operator's policy, including training for a single engine failure during takeoff. His most recent recurrent training was successfully performed on 23 August 2016.

1.5.2 The Copilot

The Copilot's files provided to the Investigation showed that he was 47 years old, holding an Airline Transport M/E LAND A330 (P2), A340, and Boeing 777, valid to 6 October 2019 with a total of 13,000 flying hours and 2,309 total hours on the aircraft type. The Copilot passed all training required by the Operator's policy including training on single engine failure during takeoff. His most recent recurrent training was successfully performed on 7 July 2016.

Table 2. Crew information

	Commander	Copilot	Team B Commander	Team B Copilot
Age	39	47	50	41
Type of License	Airline Transport Pilot License	Airline Transport Pilot License	Airline Transport Pilot License	Airline Transport Pilot License
Valid to	8/10/2021	6/10/2019	3/3/2023	23/9/2022

Rating	M/E LAND A320, A330 (P2) Boeing 777/787	M/E LAND A330 (P2), A340 B777	M/E LAND A320/A330/A340/ Boeing 777/B787	M/E LAND Boeing 777/787 (P2)
Total flying time (hours)	8130	13000	12300	8927
Total on this type (hours)	1325	2309:51	392:11	1420:55
Total last 90 days (hours)	154:40	121:53	150:03	148:25
Total on type last 90 days (hours)	154:40	121:53	150:03	148:25
Total last 7 days (hours)	7:02	14:05	8:43	19:13
Total on type last 7 days (hours)	7:02	14:05	8:43	19:13
Total last 24 hours (hours)	0	0	0	0
Last recurrent SEP[1] training	29/05/2016	6/7/2016	3/6/2016	16/7/2016
Last proficiency check	23/8/2016	7/7/2016	13/6/2016	17/7/2016
Last line check	6/12/2015	6/9/2016	19/5/2016	24/11/2015
Medical class	Class 1	Class 1	Class 1	Class 1
Valid to	25/8/2017	30/4/2017	28/2/2017	11/12/2016
Medical limitation	VDL[2]	NIL	VDL/SIC[3]	NIL

1.6 Aircraft Information

1.6.1 Aircraft general data

The Boeing-manufactured Boeing 777-3FXER, equipped with two General Electric (GE90) engines, wide-body Aircraft, was type certificated by the Federal Aviation Administration (FAA) of the United States. The Aircraft was manufactured in 2012, given a manufacturer serial number of 39687, delivered to the Operator on 20 December 2012, and issued a certificate of registration, with A6-ETL registration mark.

The Aircraft seating configuration comprised of three zones with eight first class seats, 48 seats in business class, and 282 economy class.

The Aircraft maximum take-off weight was 351,534 kg, and the maximum landing weight was 251,290 kg.

The Investigation reviewed the Aircraft maintenance records and no significant defects were found.

The Operator fitted only Bridgestone tires to the nose landing gear for the Boeing 777 fleet. This was the first incident involving Boeing 777 nose gear tire tread separation suffered by the Operator.

The daily inspection of the Aircraft tires was carried out on the Incident date, and no tire damage was observed. The most recent workshop inspection of the damaged tire was carried out on 12 July 2016 and nothing abnormal was observed.

Tire pressure readings are available on the EICAS in the cockpit. There was no EICAS indication of low pressure for any of the tires.

Tables 3 illustrates the Aircraft data.

Table 3. Aircraft data	
Manufacturer:	The Boeing Company
Model:	Boeing 777-3FXER
MSN:	39687
Date of delivery:	20 December 2012

[1] Safety and emergency procedures training

[2] Correction for defective distant vision

[3] Specific medical examination(s)

Nationality and registration mark:	United Arab Emirates, A6-ETL
Name of the owner:	Wilmington Trust Company, Delaware 19890-1605, USA.
Name of the Operator:	Etihad Airways
Certificate of registration	UAE-COR-0387
Number:	UAE-COR-0387
Issuing Authority:	UAE GCAA
Issuance date:	20 December 2012
Certificate of Airworthiness	
Number:	UAE-COA-0110
Issuing Authority:	UAE GCAA
Issuance date:	20 December 2012
Valid to:	ARC issued on 26 November 2015. Expires on 19 December 2016
Total hours since new:	21835:54
Total cycles since new:	2361
Last major inspection check, type, date and hours/cycles:	C1 Check, 06th December 2015 17493:25 FH, 1866 FC
Total hours since last major inspection:	4342:29
Total cycles since last major inspection:	495
Last Inspection prior to flight EY450, type, date and hours/cycles:	Transit Check 27th September 2016 21835:54 FH, 2361FC
Maximum Takeoff Weight:	351,534 kg
Maximum Landing Weight:	251,290 kg
Maximum Zero Fuel Weight:	237,682 kg
Fuel Uplift EY450	153,723 Liters
Departure fuel EY450	129,800 kg
Landing fuel EY450	122,900 kg
Takeoff Weight EY450	347,807 kg
Landing Weight for EY450	341,481 kg
Zero Weight for EY450	218,581 kg

1.6.2 Engine information

The No.1 engine was delivered to the Operator on 15 December 2012, and installed on the Aircraft on 11 September 2015. At the time of the Incident, the engine had performed 18,591.64 hours and 2,648 cycles since new. The No.2 engine was delivered to the Operator on 18 March 2010, and installed on the Aircraft on 6 December 2015. At the time of the Incident the engine had performed 42,226.14 hours and 7,522 cycles since new.

Tables 4 illustrates the engine data.

Table 4. Engine general data

	No.1 engine	No.2 engine
Manufacturer	General Electric	General Electric
Model	GE90-115B	GE90-115B
MSN	907115	906176
Date of delivery	15 Oct. 2012	18 Mar. 2010
Cycles since new	2,648	7,522
Hours since new	18,591.64	42,226.14
Date of Installation on A6-ETL	11 Sept. 2015	6 Dec. 2015
Cycles/hours since installation on A6-ETL	600/5,508	1,616/11,538
Cycles/hours since last overhaul	2,648/18,591.64	5,587/28,911

1.6.3 Wheel hub and tire information

The Operator's policy in relation to the re-treading of nose wheel tires allowed three retreads indicated by an R3 mark. The tire involved in the Incident had three retreads.

Table 5. Wheel hub and tire information

	No.1 nose wheel tire	No.1 nose wheel hub	No.2 nose wheel tire	No.2 nose wheel hub
Manufacturer	Bridgestone	Goodrich	Bridgestone	Goodrich
Part number	APR0600	3-1619	APR0600	3-1619
Serial number	910LJ077	0412	314LJ004	1346
Date of delivery	16 SEP 2014	14 May 2010	14 AUG 2014	26 SEPT 2014
Cycles since new	Not tracked	3177FC	Not tracked	1071
Hours since new	Not tracked	20392.09	Not tracked	7608.85FH
Number of aircraft installations	10	13	5	6
Date of last removal	27 SEP 2016	27 SEP 2016	27 SEP 2016	27 SEP 2016
Date of installation on A6-ETL	29 AUG 2016	29 AUG 2016	03 AUG 2016	03 AUG 2016
Hours/cycles since last installation	402.6/49	402.6/49	779.48/98	779.48/98
Number of rework or re-treading	R3	N/A	R2	N/A

1.7 Meteorological Information

The Incident occurred during daylight. The weather information at Abu Dhabi International Airport, between 1000 and 1420 LT, indicated that it was Cloud and Visibility OK (CAVOK), with a wind speed of between 5 to 12 kt from south, and ground temperature range between 34 °C and 39 °C. At the time of takeoff, the wind speed was between 5 and 8 kt, and the temperature was 36 °C.

The Investigation determined that weather was not a factor in this Incident.

Table 6. METAR information for Abu Dhabi International Airport

SPECI OMAA 271020Z 31011KT 280V350 CAVOK 39/22 Q1007 NOSIG
METAR OMAA 271000Z 09005KT 040V140 CAVOK 39/19 Q1007 BECMG 31012KT
METAR OMAA 270900Z 13003KT CAVOK 38/19 Q1007 BECMG 31012KT
METAR OMAA 270800Z 20005KT 140V280 CAVOK 37/21 Q1008 BECMG 31012KT
METAR OMAA 270700Z 18008KT CAVOK 36/20 Q1009 NOSIG
METAR OMAA 270600Z 14012KT CAVOK 34/20 Q1010 NOSIG

1.8 Aids to Navigation

Ground-based navigation aids, on-board navigation aids, aerodrome visual ground aids, and their serviceability were not a factor in this Incident.

1.9 Communications

Ground-based communication aids and on-board communication aids were not a factor in this Incident

1.10 Aerodrome Information

Abu Dhabi International Airport is located 30.6 kilometres east of the center of Abu Dhabi city, the United Arab Emirates. The airport elevation is 88 feet.

The airport is equipped with two asphalt runways: 13R/31L and 13L/31R, both with lengths of 4,100 meters.

The airport is equipped with closed-circuit television (CCTV) partially covering the runways, taxiways, and manoeuvring area.

1.10.1 Aircraft stand maneuvering guidance lights

Aircraft stand maneuvering guidance lights should be provided to facilitate the positioning of an aircraft stand on a paved apron or on a de-icing/anti-icing facility intended for use in poor visibility conditions, unless adequate guidance is provided by other means.

Annex 14, paragraph 5.3.1.7, states:

"Light fixtures inset in the surface of runways, stop-ways, taxiways and aprons shall be so designed and fitted as to withstand being run over by the wheels of an aircraft without damage either to the aircraft or to the lights themselves".

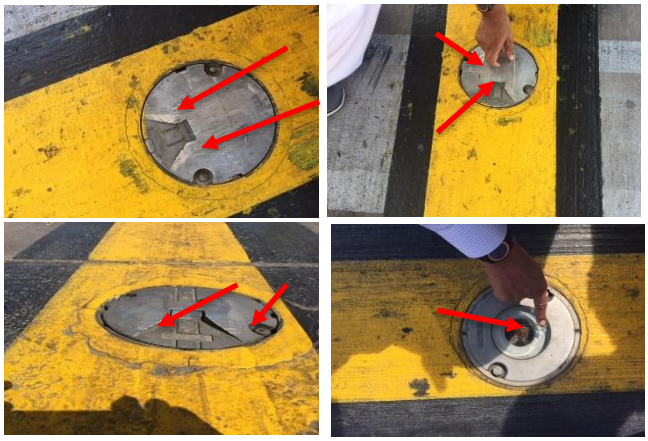

Figure 8. Types of lights in the parking bays (OMAA) [Arrows indicate sharp edges]

In the aircraft maneuvering area of Abu Dhabi International Airport, a THORN:IN SBW 40 W lights were used, and the Stand Lead On Lights were CCH: FAA L 852E.

The Investigation found some of these lights with sharp edges (figure 8) which had the potential to cause damage to aircraft tires.

1.10.2 Abu Dhabi International Airport FOD management:

The *Aerodrome Manual* described the FOD management policy as:

> *"6.8.1. Abu Dhabi Airports airside operations departments and service provider units operating on the airside shall ensure runways, taxiways and aprons are clear of loose stones or other objects and debris that could cause damage to aircraft or engines, or impair the operation of aircraft systems. Aircraft systems include but are not limited to turbine engines, propellers, aircraft skin and tires".*

This policy was implemented through the use of runway, taxiway, and ramp visual inspections which were carried out every four hours by the airport operation department safety team.

The airport was not equipped with an automated FOD detection system, and the methods of detecting FOD involved apron airside safety team inspections and observations. The FOD was picked up and placed in dedicated FOD bins located on the aircraft stands by personnel who work on the ramp. Records of the results of each inspection were maintained.

Vehicles employed to sweep the ramp and other aircraft maneuvering areas were not equipped with magnets to capture and retain metallic items of FOD.

The airport ramp staff were trained on FOD awareness on a recurrent basis. The training covered briefing on FOD for participants, and were conducted daily by the Airside Safety Team before the FOD walk. This training focused on that no person shall place,

discharge, or deposit any litter on the airside except in the containers provided. All ground handling agents engaged in servicing or handling aircraft shall inspect the aircraft stand to ensure FOD and other litter arising from their operations are, and the control and disposal of FOD is the responsibility of all airport users and staff. There was a bin at each stand, which was labelled FOD. Additionally, posters were displayed at the airport to maintain FOD awareness.

1.11 Flight Recorders

The Aircraft was equipped with a digital flight data recorder (DFDR) and cockpit voice recorder (CVR) as described in table 7.

Table 7. Flight recorders

	Type	Part number	Serial number
CVR	L-3 Aviation Recorder	2100-1025-22	000823255
DFDR	L-3 Aviation Recorder	2100-4045-22	000701435

The CVR and the DFDR were removed from the Aircraft and made available to the Investigation. The flight recorders were received by the AAIS flight recorders laboratory, in Abu Dhabi, the United Arab Emirates, for data retrieval, and were successfully downloaded and read out.

1.11.1 Flight data recorder

The results of the DFDR data analysis were represented in graphical format as plots and comma-separated value files (CSV), with tabulated data in a spreadsheet format. These plots were synchronized and the CVR transcript was superimposed on the plots.

1.11.2 Cockpit voice recorder

The CVR raw data was downloaded and processed to write the audio transcript.

1.12 Wreckage and Impact Information

The Aircraft was intact following the Incident.

1.13 Medical and Pathological Information

No medical or pathological investigations were conducted because of this Incident.

1.14 Fire

There was no signs fire.

1.15 Survival Aspects

The airport rescue and firefighting services attended to the Aircraft immediately after landing, and the Commander was updated that there were no signs of fire. The passengers and the crewmembers disembarked on the runway using two passenger stairs positioned at doors R1 and R2 doors.

1.16 Tests and Research

Both nose gear tires were examined and tested by the manufacturer.

1.16.1 Appearance observation

For the purpose of testing, the manufacturer identified three relevant areas of the damaged tire; A, B and C (figure 9).

A physical inspection, carried out by the manufacturer, revealed that in the tire tread (crown/shoulder):

- All of the tread ribs, cut-protector and part casing belt cords were detached from the tire casing (figure 10).
- About 80% of the total tread debris was collected for examination purposes (figure 11).
- Inner liner, both sidewalls and both bead areas were in a normal condition (figure 12 is showing the wheel structure).

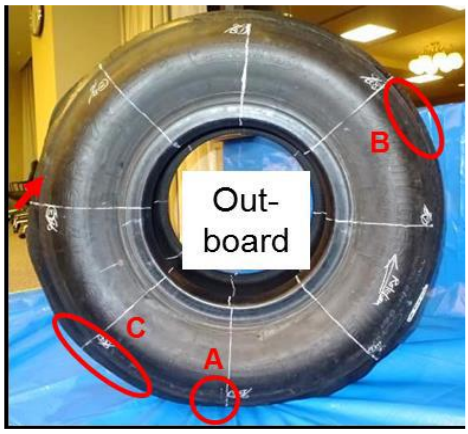

Figure 9. Locations of zones A, B and C

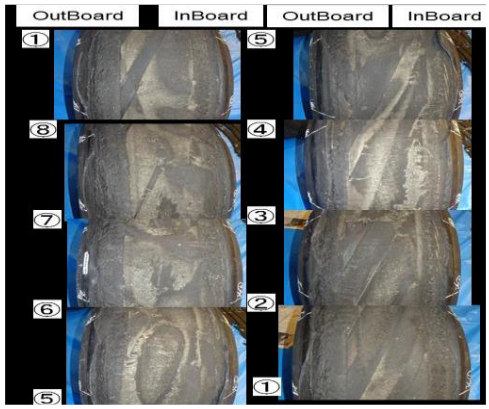

Figure 10. No.1 nose wheel tire casing surface

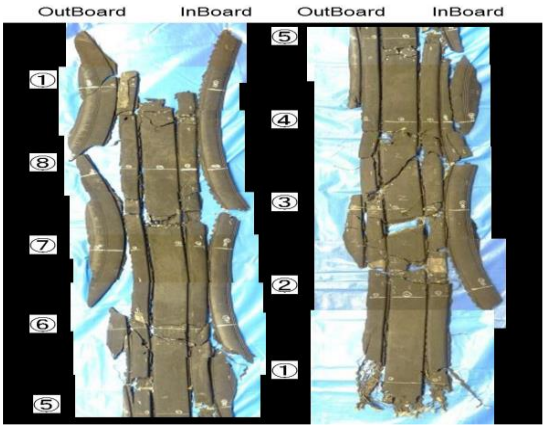

Figure 11. Collected detached tread pieces from No. 1 NLG tire

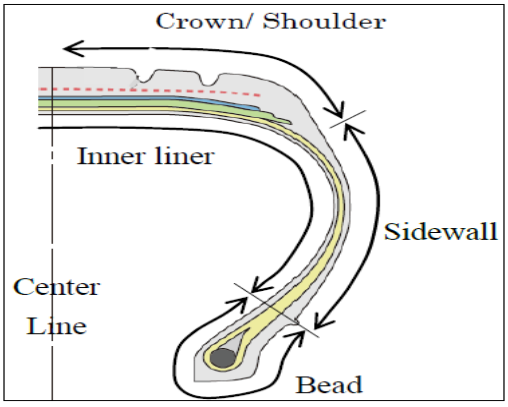

Figure 12. NLG Tire, wheel structure

1.16.2 Shearography[4] test of the damaged tire

Shearography inspection report of the damage casing indicated that there was no anomaly in the crown area of the casing where the tread rubber detached, and there were two small areas of trapped air in the bead area of the Inboard side, which had no connection to the tread detachment (figure 13).

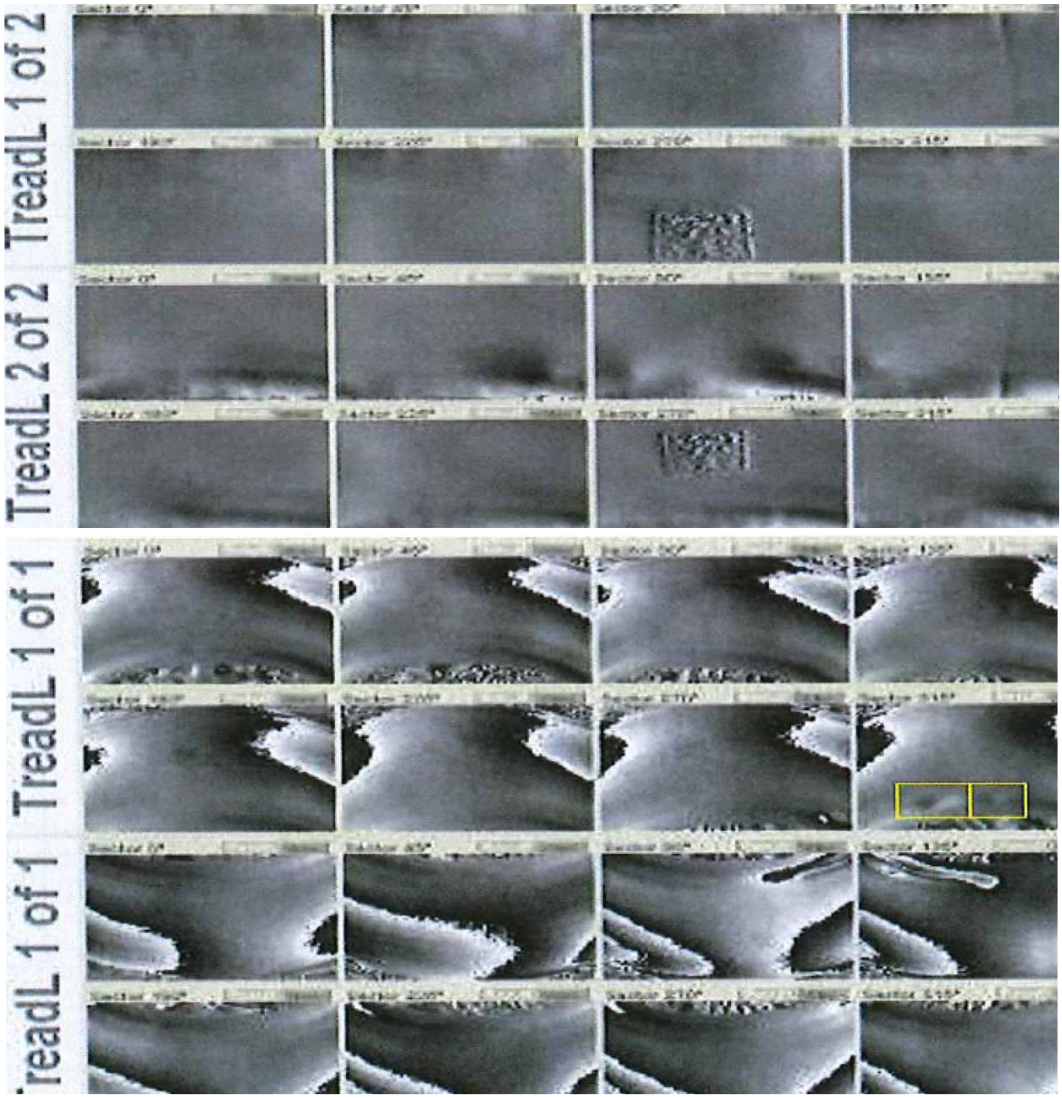

Figure 13. Shearography test

[4] Shearography test: accurate, real-time information about internal material discontinuities and inconsistencies on large and small surfaces. This portable, non-contacting method can detect extremely small, defect induced deformations in surface profiles indicating a hidden flaw or stress point such as

- Impact and heat damage
- Disbands, unbounds, and delamination
- Core damage
- Foreign Objects and Debris
- Epoxy Matrix Deficiency or Excess
- Near Surface Cracks
- Fluid Ingress
- Loose Fiber Tows

1.16.3 Possible start zones

Zone A

Striation in shoulder area on casing was observed at Zones A, B and C locating individually (figure 14). Also characteristic damage consisting of a sharp cut was observed on the crown area.

A series of striation marks were observed coming from the inside of the shoulder rib. No striation marks had progressed to the center and second rib. Chevrons and discolored rubber was observed on the shoulder pieces, but not the second rib pieces. Also, an area of skidding located under the second rib pieces beside the chevrons and discolored rubber was identified.

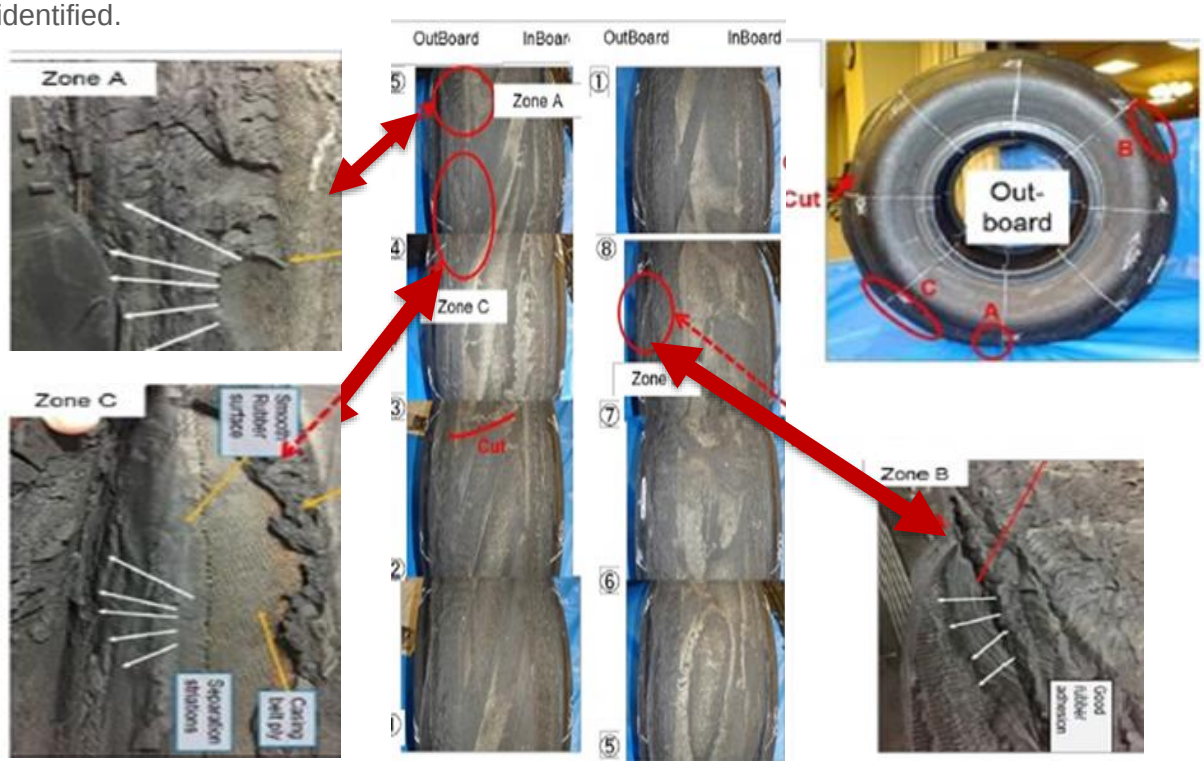

Figure 14. Possible initial foreign object damage

Based on these facts, it was estimated that the second rib detached before the occurrence of the chevrons, discolored rubber and skid indication above the casing. After the second rib detached, the surface of the casing, the outer edge of the second rib and the shoulder groove area contacted on the runway at touchdown (figure 15).

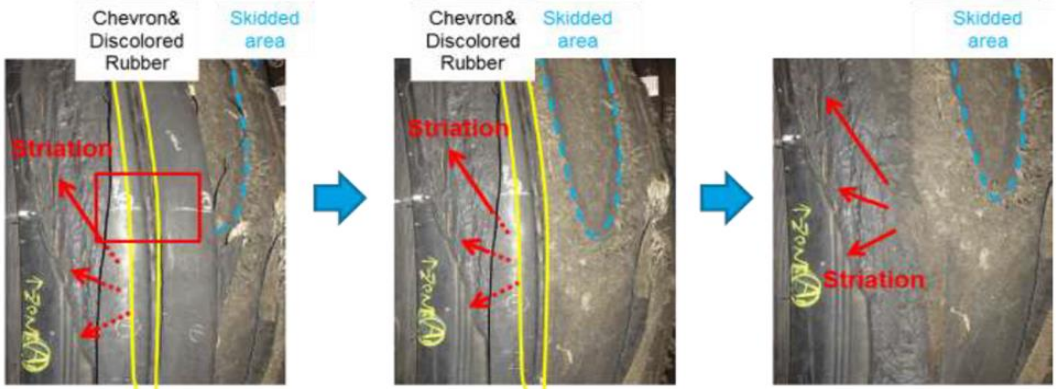

Figure 15. Tire damage, zone A

Zone B

Lateral scratches with 1 – 4 cm length were observed on the surface of the detached shoulder rib (figure 16).

Figure 16. Damaged tire, zone B

Zone C

Fracture damage was observed in zone c (figure 17).

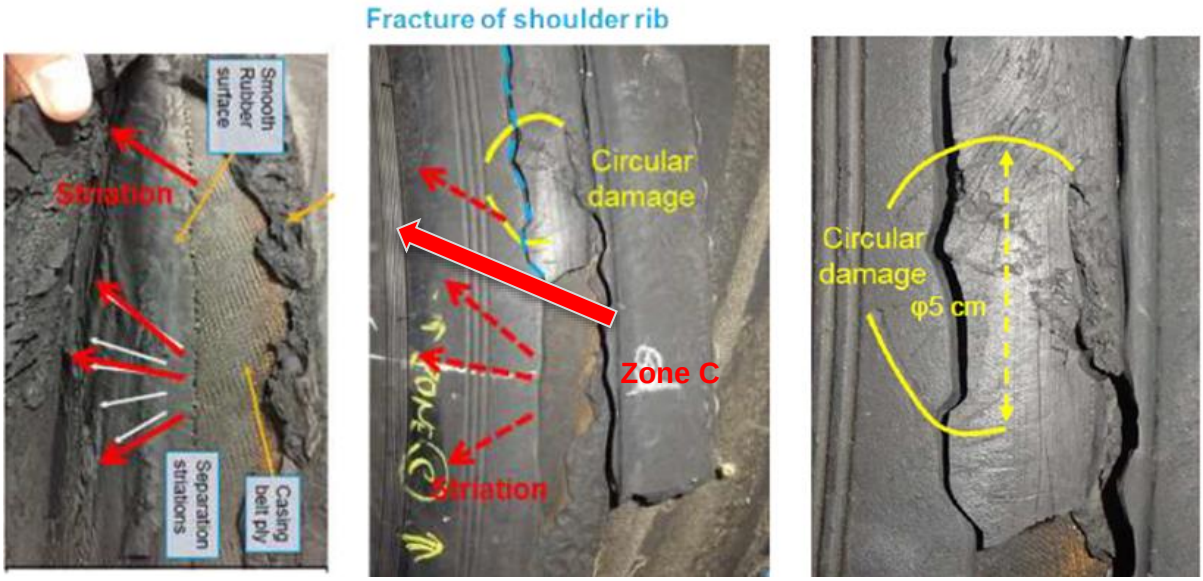

Figure 17. Damaged tire, zone C

1.16.4 Inspection results

The examination of the damaged tire and associated debris indicated that the tire crown tread area sustained damage due to contact with a sharp foreign object. It is not known when or where this damage occurred.

The tread detachment of zones A and B as shown in figures 9 and 10, occurred as the Aircraft rotated on takeoff. The zone C tread detachment occurred at almost the same time as the tread detachment from zones A and B.

1.17 Organizational and Management Information

1.17.1 The Operator

Etihad Airways was established in July 2003 and is wholly owned by the Government of Abu Dhabi.The Operator is based in Abu Dhabi, and holds an air operator certificate (AOC) issued by the GCAA.

The Operator's fleet consists of 122 aircraft, comprising 35 Airbus A320 family, 25 Airbus A330 family, eight Airbus A380, 12 Boeing 787, 24 Boeing 777 family, five Airbus A330-200F (freighter) and five Boeing 777-200F (freighter).

The requirements for obtaining an AOC are generally defined but not limited such as:

- Sufficient personnel with the required experience for the type of operations requested,
- Airworthy aircraft, suitable for the type of operations requested,
- Acceptable systems for the training of crew and the operation of the aircraft (*Operations Manual*)
- A quality system to ensure that all applicable regulations are followed,
- The appointment of key accountable staff, who are responsible for specific safety critical functions such as training, maintenance and operations,
- The operator has sufficient ground infrastructure, or arrangements for the supply of sufficient infrastructure, to support its operations into the aerodromes requested.

1.17.2 Etihad Airport Services Ground

Etihad Airport Services Ground, is responsible at Abu Dhabi International Airport for the pushback of departing aircraft from terminals or parking bays, baggage handling, loading and unloading of aircraft, provision and operation of aircraft servicing equipment, aircraft cabin cleaning and guest and crew transport to and from aircraft.

Etihad Airport Services Ground operates more than 3,800 pieces of ground support equipment, and is capable of handling all aircraft types.

1.17.3 The aerodrome operator

The aerodrome operator is responsible for actively managing the aerodrome for which the Duty Manager is responsible, to enable a safe operating environment such as to facilitate all aircraft using the airport with standard services as to provide standard runways, taxiways, parking bays and manoeuvring areas.

1.18 Additional Information

1.18.1 Aircraft daily check

On the day of the Incident, the daily check was carried out and included the inspection of the nose landing gear tire pressures, which were 226 psi for the left and 227 psi for the right tire.

1.18.2 Aerodrome inspection

As per the Abu Dhabi International Airport safety management system, the airport Operations Department is responsible for airfield safety inspections of the aircraft maneuvering area, ramp and service roads.

Airside users identify safety hazards, which may also be identified during airfield safety inspections, and the Airside Safety Department ensures that the necessary corrective actions are taken to mitigate identified hazards. The Airside Safety Department is responsible for safety inspections:

> *"5.10.3. At Abu Dhabi International Airport, the daily maneuvering area inspections will be conducted at least four times daily by Airfield Safety Inspection Team. The Apron Airside Safety Team is responsible for conducting inspections on the service roads and aprons at least four times daily."*

A post-Incident inspection performed by AAIS noted that many stand centerline lights had sharp edges.

1.18.3 Automated FOD detection

In 2005, the Federal Aviation Administration (FAA), in cooperation with the University of Illinois, conducted a preliminary short term evaluation of an automated FOD detection system.

Through the use of millimeter wave length radar, this system demonstrated that it was capable of detecting objects as small as a two-inch long bolt on the pavement surface. As a result, it was determined that this type of system could provide airport personnel with immediate FOD alerts, and also provide specific information on where the object is located.

In the United Arab Emirates, Dubai International Airport installed an automated FOD detection system. The system went into operation on 1 March 2017. The system is currently effective in identifying FOD and achieves its objective.

1.18.4 Tire failure history

The tire manufacturer reported that this Incident was the first occasion of Boeing 777 nose gear tire debris being ingested by an engine leading to damage to the engine.

The occurrence rate of tire tread detachment caused by FOD for the nose wheel tires, in the period from 2012 to 2016, was 165 failures per million flights.

The tire manufacturer has no experience of tread detachment caused by operating in high temperatures of over 50 °C.

2. Analysis

2.1 General

The Incident occurred during rotation when the No.1 nose wheel tire shed its tread, causing damage to the fuselage aft of the NLG bay and the ingestion into the No.1 engine of tire debris which led to the failure of the engine.

The No.2 engine inboard fan cowling was struck by tire debris, but the cowling was not damaged. No tire debris was ingested by the No.2 engine.

2.2 Risk Analysis

On separation of the No.1 nose wheel tire tread the tread broke into pieces, and the pieces travelled in different directions and impacted several areas of the Aircraft. The impacted areas included the No.1 engine, which ingested tire debris, the lower fuselage aft of the NLG bay and the inboard fan cowling of the No.2 engine. There was significant potential for the No.2 engine to ingest some pieces of debris, which could have resulted in a more hazardous situation than actually occurred during this Incident.

The Aircraft manufacturer had not performed a risk analysis of the possibility of nose wheel tire debris being ingested into one or both engines potentially leading to engine failure.

2.3 Abu Dhabi International Airport FOD Management and Detection System

The airport was not equipped with an automated runway FOD detection system. The safety team manually inspected and removed debris from the maneuvering areas.

The airport closed-circuit television (CCTV) system did not cover all of the aircraft parking areas. Some sections of taxiways and runways were also not covered.

The FOD sweepers were not equipped with magnets and therefore were not as effective as they should have been in removing potentially sharp metallic debris from maneuvering areas.

2.4 Nose Gear Tire Damage

As the Aircraft was rotated during takeoff at V_2 speed, as the nose gear was lifting off the runway, the No.1 nose wheel tire tread separated from the tire. Pieces of the separated outer layer impacted and damaged the lower fuselage aft of the NLG bay and several pieces were ingested by the No.1 engine. Tire debris also struck the No.2 engine inboard fan cowling.

The No.1 engine sustained damage to the fan, compressor, and hot section. The ingested tire debris caused the No.1 engine to automatically shut down. The No.2 engine fan cowling was undamaged and no tire debris was ingested. Following the tread separation, the No.1 nose wheel tire remained inflated.

Although, in the Incident flight the pushback was conducted using a conventional tug and tow-bar combination, the examination of the damaged tire revealed that the initiation point of the tire outer layer separation resulted from either an FOD encounter, or from a tire cut caused by a towbarless tug. Therefore, this initiation point of the tire outer layer cut could be happened in one of the resent previous flights in any one of the airports used by the Aircraft.

A detailed search of the taxi route followed by the Aircraft, and of the runway and surrounding area, did not locate any item of possible FOD.

2.5 Analysis of Nose Gear Tire Failure

2.5.1 The Operator's tires retread policy

The Operator's policy in relation to re-treading of tires allowed three retreads. The No.1 nose wheel tire had undergone three retreads. The number of retreads was not considered contributory to the Incident as the tread separation resulted from FOD damage suffered by the tire and not from any defect resulting from retreading.

No anomalies were found in either the tire manufacturing process, or the tire retreading process.

2.5.2 Possible tread separation initiation zone

Striation in the shoulder area of the tire casing was observed in three areas; zones A, B and C. Also, characteristic damage due to contact with a sharp object was observed in the crown area (figures 9, 10 and 11).

2.5.3 Tread separation mechanism:

The crown tread area suffered damage due to contacting a sharp foreign object. Sometime later tread separation occurred in zones A and B. It is not known when the tire sustained the FOD damage. The damage event may have occurred during a previous flight at a different airport.

Additionally, zone C sustained circular shaped foreign object damage at an unknown time and location. Tread separation in zone C occurred at almost the same time as tread separation in zones A and B.

Zone A:

A series of striation marks were observed from the inside of the shoulder rib to the outer side of the shoulder rib (figure 16). There was no striation which progressed to the center and 2nd rib. Chevrons and discolored rubber was observed on the shoulder piece, beside the chevrons and discolored rubber. Based on these facts, it is estimated that the 2nd rib detached before occurrence of chevron, discolored rubber and the skid above the casing, the outer edge of the 2nd rib and shoulder groove area contacted on runway at touch down. After that, the shoulder rib detached due to severe striation caused by tire loading and centrifugal force during tire rotation after touch down.

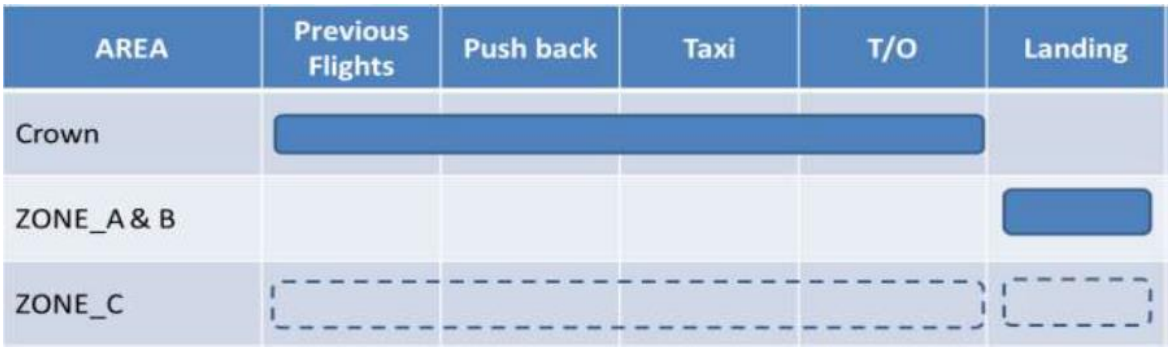

Table 8. Estimated scenario of damage by timeline

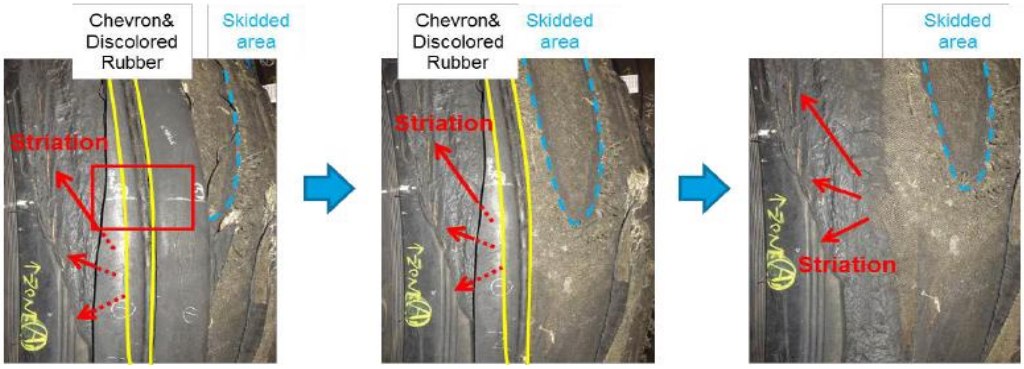

Figure 18. No.1 nose wheel tire damage characteristics

2.6 Crew Performance

The Investigation evaluated the flight crew actions taken during the period from when they felt severe vibration just after rotation, through the No.1 engine failure and until the Aircraft landed. The flight crew followed the Operator's procedures in dealing with all aspects of the event and for a single engine overweight landing.

2.7 Engine Failure

During takeoff, following the tire tread separation, and the No.1 engine ingestion of the tire debris, and subsequent uncommented inflight shutdown, the No.2 engine inboard fan cowling was struck by tire debris. This could lead to a risk of ingestion of tire debris by the No.2 and consequent damage to the engine.

2.8 Aerodrome Information

2.8.1 Aircraft stand maneuvering guidance lights

The Investigation found that some of the aircraft stand maneuvering guidance lights had sharp edges (figure 9). This had the potential to cause damage to aircraft tires.

The following actions have been taken concerning the sharp edges:

(a) The reason for the sharp edges to the lights near the stands was investigated. It was identified that the towbarless tugs, while disengaging from aircraft, caused damage to the lights.

(b) Once the main reason for the sharp edges was identified, training to the tug operators was undertaken to educate them about the subject, and advise them not to disengage the tugs near the lights.

2.8.2 FOD awareness

The presence of foreign objects in an airport environment presents a hazard to aircraft safety. The presence of FOD can result from the loss of parts from aircraft or vehicles, pavement cracking, wildlife, or construction work.

Identification of FOD at airports requires regular observation and inspection of airport surfaces by airport personnel, or by observation by flight crew operating on the airport pavement. Removal of such FOD is only triggered by actual observation.

FOD posters have been positioned in various locations by the airport authority to serve as reminders to staff of the hazard posed by FOD. Information about FOD is also provided to staff during training.

3. Conclusions

3.1 General

From the evidence available, the following findings, causes and contributing factors were made with respect to this Incident. These shall not be read as apportioning blame or liability to any particular organization or individual.

To serve the objective of this Investigation, the following sections are included in the conclusions heading:

- **Findings.** Statements of all significant conditions, events or circumstances in this Incident. The findings are significant steps in this Incident sequence but they are not always causal or indicate deficiencies.
- **Causes.** Actions, omissions, events, conditions, or a combination thereof, which led to this Incident.

3.2 Findings

3.2.1 Findings relevant to the Aircraft

(a) The Aircraft was certificated, equipped and maintained in accordance with the existing requirements of the *Civil Aviation Regulations* of the United Arab Emirates.

(b) The Aircraft was airworthy when it was prepared for flight prior to the Incident.

3.2.2 Findings relevant to the flight crew

(a) The flight crew were licensed and qualified for the flight in accordance with existing requirements of the *Civil Aviation Regulations* of United Arab Emirates.

(b) The flight crew held valid class 1 medical certificates and they were adequately rested to operate the flight.

3.2.3 Findings relevant to Abu Dhabi International Airport

(a) Abu Dhabi International Airport was not equipped with an automated FOD detection system to cover the runways, taxiways and maneuvering areas.

3.2.4 Findings relevant to the Aircraft Manufacturer

(a) The Aircraft manufacturer did not perform a risk analysis of the possibility of nose wheel tire debris being ingested into one or both engines potentially leading to engine damage or failure.

3.3 Causes

The shedding of the No.1 nose wheel tire tread occurred as a result of the tire contacting foreign object debris. Subsequently, the damaged tire debris was ingested by the No.1 engine causing engine failure.

4. Safety Recommendations

4.1 Safety Recommendations addressed to the General Civil Aviation Authority (GCAA) of the United Arab Emirates

It is recommended that the GCAA assure that United Arab Emirates aerodrome operators:

SR18/2018

conduct regular inspections and audits on the airport ground lights fittings to ensure that they remain free of sharp edges or loose bolts that could have the potential to cause damage to aircraft tires.

SR19/2018

implement mitigations to prevent damage to airport ground lights caused by towbarless tugs.

SR20/2018

carry out risk assessment for to determine whether an automated FOD detection system is crucial to be installed or not.

SR21/2018

supervise a study on the need of a requirement for airports to be equipped with runway and taxiway sweepers fitted with magnets to attract ferrous foreign objects.

4.2 Safety Recommendation addressed to Abu Dhabi International Airport

It is recommended that Abu Dhabi International Airport:

SR22/2018

install automatic foreign objects detection system.

4.3 Safety Recommendation addressed to the Federal Aviation Administration (FAA) of the United States

It is recommended that the FAA:

SR23/2018

evaluate a requirement for The Boeing Company to carry out a risk assessment of nose landing gear tire debris being ingested into both aircraft engines following tire failure or tread shedding.

This Final Report is issued by:

The Air Accident Investigation Sector
General Civil Aviation Authority
The United Arab Emirates

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Appendix A. Flight Takeoff Profile