

AIRCRAFT SERIOUS INCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:		CA18/3/2/1447	
Aircraft Registration	ZS-FGE	Date of Incident		21 April 2024		Time of Incident	1205Z
Type of Aircraft		Boeing 737-800		Type of Operation		Air Transport (Part 121)	
Pilot-in-command Licence Type		Airline Transport Pilot Licence		Age	32	Licence Valid	Yes
Pilot-in-command Flying Experience		Total Flying Hours		4 667.43		Hours on Type	3 504.36
Last Point of Departure		O.R. Tambo International Aerodrome (FAOR), Gauteng Province					
Next Point of Intended Landing		Cape Town International Aerodrome (FACT), Western Cape Province					
Damage to Aircraft		Minor					
Location of the incident site with reference to easily defined geographical points (GPS readings if possible)							
On Runway 21R at FAOR (GPS position: 26°07'44.23" South 028°14'23.05" East)							
Meteorological Information		Surface wind: 190°/5kt; Temperature: 27°C; Dew point: 4°C; Visibility: CAVOK					
Number of People On-board	6+178	Number of People Injured	0	Number of People Killed	0	Other (On Ground)	0
Synopsis							
On Sunday morning, 21 April 2024 at approximately 0948Z, a Boeing 737-800 aircraft with registration ZS-FGE was taking off on a domestic commercial flight from O.R. Tambo International Aerodrome (FAOR) in Gauteng province to Cape Town International Aerodrome (FACT) in Western Cape province when the left outer (No.1) mainwheel separated from its axle during rotation. The crew opted to fly to the hold to burn off fuel. After being airborne for 2 hours and 17 minutes, the crew was cleared to land on Runway 21R at FAOR. The landing was uneventful; however, approximately 30 metres (m) before the aircraft was brought to a stop on the runway, the left inner (No. 2) mainwheel tyre burst. No person was injured during the serious incident. The failed wheel hub components indicated that the most likely cause of the wheel hub failure was due to a fatigue crack that initiated at the bearing cup seat transition of the inboard wheel hub bearing bore.							
Probable Cause and/or Contributory Factor							
It is likely that the cause of the wheel hub failure was due to a fatigue crack that initiated at the bearing cup seat transition of the inboard wheel hub half bearing bore.							
SRP date		14 October 2025		Publication date		15 October 2025	

Occurrence Details

Reference Number : CA18/3/2/1447
Occurrence Category : Serious Incident (Category 1)
Type of Operation : Air Transport Operations (Part 121)
Name of Operator : FlySafair
Aircraft Registration : ZS-FGE
Aircraft Make and Model : Boeing 737-800
Nationality : South African
Place : O.R. Tambo International Aerodrome (FAOR)
Date and Time : 21 April 2024 at 1205Z
Injuries : None
Damage : Minor

Purpose of the Investigation

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011, this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and not apportion blame or liability.

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Investigation Process

The Accident and Incident Investigations Division (AIID) of the South African Civil Aviation Authority (SACAA) was notified of an occurrence on 21 April 2024 at 1200Z. The occurrence was categorised as a serious incident according to the CAR 2011 Part 12 and the International Civil Aviation Authority (ICAO) STD Annex 13 definitions. A notification was sent to the State of Design and Manufacturer in accordance with the CAR 2011 Part 12 and the ICAO Annex 13 Chapter 4. The State appointed a non-travelling accredited representative and advisor. The investigators were dispatched to the serious incident site.

Notes:

- Whenever the following words are mentioned in this report, they shall mean the following:*
Serious Incident — this investigation serious incident
Aircraft — the Boeing 737-800 involved in this serious incident
Investigation — the investigation into the circumstances of this serious incident
Pilots — the pilots involved in this serious incident
Report — this serious incident report
- Photos and figures used in this report were taken from different sources and may have been adjusted from the original for the sole purpose of improving clarity of the report. Modifications to images used in this report were limited to cropping, magnification, file compression; enhancement of colour, brightness, and contrast; or addition of text boxes, arrows, or lines.*

Disclaimer

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Abbreviation	Description
°	Degrees
°C	Degrees Celsius
AAIB	Aircraft Accident Investigation Branch
AGL	Above Ground Level
AIID	Accident and Incident Investigations Division
AMO	Aircraft Maintenance Organisation
AOC	Air Operating Certificate
ARFF	Aerodrome Rescue and Firefighting
ATC	Air Traffic Control
ATPL	Airline Transport Pilot's Licence
ATSB	Australian Transport Safety Bureau
C of A	Certificate of Airworthiness
C of R	Certificate of Registration
CAR	Civil Aviation Regulations
CMM	Component Maintenance Manual
CRS	Certificate of Release to Service
CVR	Cockpit Voice Recorder
FACT	Cape Town International Aerodrome (ICAO designation)
FAOR	O.R. Tambo International Aerodrome (ICAO designation)
FCTM	Flight Crew Training Manual
FDR	Flight Data Recorder
FO	First Officer
FSH	Full Screen Height
ft	feet
GPS	Global Positioning System
hPa	Hectopascal
ICAO	International Civil Aviation Organisation
kg	kilogram(s)
kt	knots
m	metres
METAR	Metrological Aerodrome Report
MTOW	Maximum Take-off Weight
NDT	Non-Destructive Testing
OEM	Original Equipment Manufacturer
PF	Pilot Flying
PIC	Pilot-in-command
psi	Pounds per Square Inch
QAR	Quick Access Recorder
QNH	Barometric Pressure Adjusted to Sea Level
QRH	Quick Reference Handbook
SACAA	South African Civil Aviation Authority
SAWS	South African Weather Service
SB	Service Bulletin
SIL	Service Information Letter
TBO	Time Between Overhaul
UTC	Universal Co-ordinated Time
UT	Ultra-Sonic Testing
WoW	Weight on or off Wheels
Z	Zulu (Term for Universal Co-ordinated Time - Zero Hours Greenwich)

1. FACTUAL INFORMATION

1.1 History of Flight

- 1.1.1 On Sunday morning, 21 April 2024, a Boeing 737-800 aircraft with registration ZS-FGE was taking off on a scheduled domestic flight FA212 from O.R. Tambo International Aerodrome (FAOR) in Gauteng province to Cape Town International Aerodrome (FACT) in Western Cape province when the serious incident occurred. Six crew members and 178 passengers were on-board the aircraft. The flight was conducted under the provisions of Part 121 of the Civil Aviation Regulations (CAR) 2011 as amended.
- 1.1.2 The flight deck crew (pilot-in-command [PIC] and first officer [FO]) as well as the four cabin crew members signed in for duty at 0830Z after being called from standby. The crew requested a fuel uplift of 12 000 kilograms (kg), which would have been adequate for the flight from FAOR to FACT, and back to FAOR. The take-off weight was 69 736 kg with flap 1 selected for take-off. The take-off decision speed (V1) was 156 knots (kt), the take-off safety speed (V2) was 156 knots, and the rotation speed (Vr) was 159 knots. The PIC was the pilot flying (PF).
- 1.1.3 According to the radar and voice communication data, the air traffic control (ATC) personnel cleared the aircraft for take-off from Runway 21R, the aircraft was airborne at 09:48:51Z with the rotation speed captured at 161 knots. As the aircraft took off, a cabin crew member who was seated at the back of the aircraft observed, through a porthole window, that the wheel had separated from the aircraft. After the seatbelt signs had switched off, the cabin crew member alerted the flight deck crew about the separated wheel. The cabin crew member and the senior cabin crew member were, thereafter, summoned to the flight deck where the PIC informed them that one of the left main wheels had dislodged during take-off. The ATC personnel also informed the crew that the wheel had come off. This was after the crew of flight FA396 had informed the ATC personnel. The PIC communicated to the senior cabin crew member that they would proceed to the hold, west of the Swartkop Air Force Base (FASK), to burn off fuel before returning to FAOR for landing. The PIC also informed the passengers about the occurrence, and that the cabin crew will prepare the cabin for an emergency landing. The passengers were kept updated throughout the flight about the measures being taken. The cabin crew remained seated for most of the flight whilst the aircraft was in the hold. Later, the ATC personnel informed the flight crew that pieces of the brake assembly had been found next to the runway. As a result, the flight crew declared a PAN PAN PAN. There was no Non-normal Quick Reference Handbook Checklist for the nature of the emergency; therefore, the crew consulted the Flight Crew Training Manual (FCTM) for guidance under the subheadings *“Tire Failure During or After Take-off”* and *“Landing on a Flat Tire”* as well as *“Partial or all Gear Up Landing”*, which they concurred were the most appropriate actions considering the similarities between the situation they were in, and the guidance prescribed in the FCTM.

- 1.1.4 After being in the hold (holding pattern) for approximately 90 minutes, the crew enquired from the ATC personnel if they could perform a low fly pass at their maintenance facility at FAOR with the landing gear extended to enable the technicians to assess the left main landing gear and advise accordingly. The request was granted, and the aircraft was cleared to 6 500ft, which was approximately 1 000ft above ground level (AGL). *Figure 2 shows the missing left outer mainwheel.*



Figure 1: The aircraft with the missing left outer mainwheel.

After the low fly pass, the aircraft climbed to 10 000ft and flew back to the hold for approximately 35 minutes during which the flight crew decided to perform a normal landing after confirming that the left inner mainwheel was still attached to the aircraft; they planned to land with a weight of 62 000 kg and with the wing flaps set at 40° at a speed of 133 kts. Radar control vectored the aircraft for landing on Runway 21R. At approximately 500 ft AGL, the PIC commanded for “brace” position, which the cabin crew members had communicated to and rehearsed with the passengers whilst the aircraft was still in the hold.

- 1.1.5 The aircraft was then cleared to land on Runway 21R; it touched down (weight on wheels) at 12:05:58Z at a speed of 135 kts with a G-load of 1.062g. A video footage reviewed by the investigators showed that the aircraft had landed normally; however, approximately 30m before the aircraft came to a stop on the runway, the left inner mainwheel tyre burst. Data obtained from the Quick Access Recorder (QAR) indicated that the PF applied brakes during the latter part of the landing roll with the initial brake pressures captured at 671 pounds per square inch (psi) on the left side, and 729 psi on the right side. The maximum brake pressure recorded during this period was 1 835 psi on the left side and 820 psi on the right side. The pilot continued to apply brakes until the aircraft came to a stop on the runway in a left wing-low attitude.

- 1.1.6 After the aircraft had stopped, the PIC instructed all crew and passengers to remain seated. Upon the arrival of the Aerodrome Rescue and Firefighting (ARFF) personnel, the crew was requested to shut down the engines as smoke was observed emanating from the left main gear. The PIC broadcasted to all occupants in the aircraft to remain seated. No person was injured during the landing sequence. After the ARFF personnel had declared the aircraft safe, the PIC informed the passengers that they would be deplaning the aircraft normally on the runway via the front left exit door and that they would be transported by bus to the terminal building. The crew members were released from further duties; they were debriefed by the operator representatives. The mainwheel that separated from the axle was recovered within the aerodrome parameters.
- 1.1.7 The serious incident occurred during the day, shortly after rotation from FAOR, at Global Positioning System (GPS) co-ordinates determined to be 26°07'44.23" South 028°14'23.05" East.

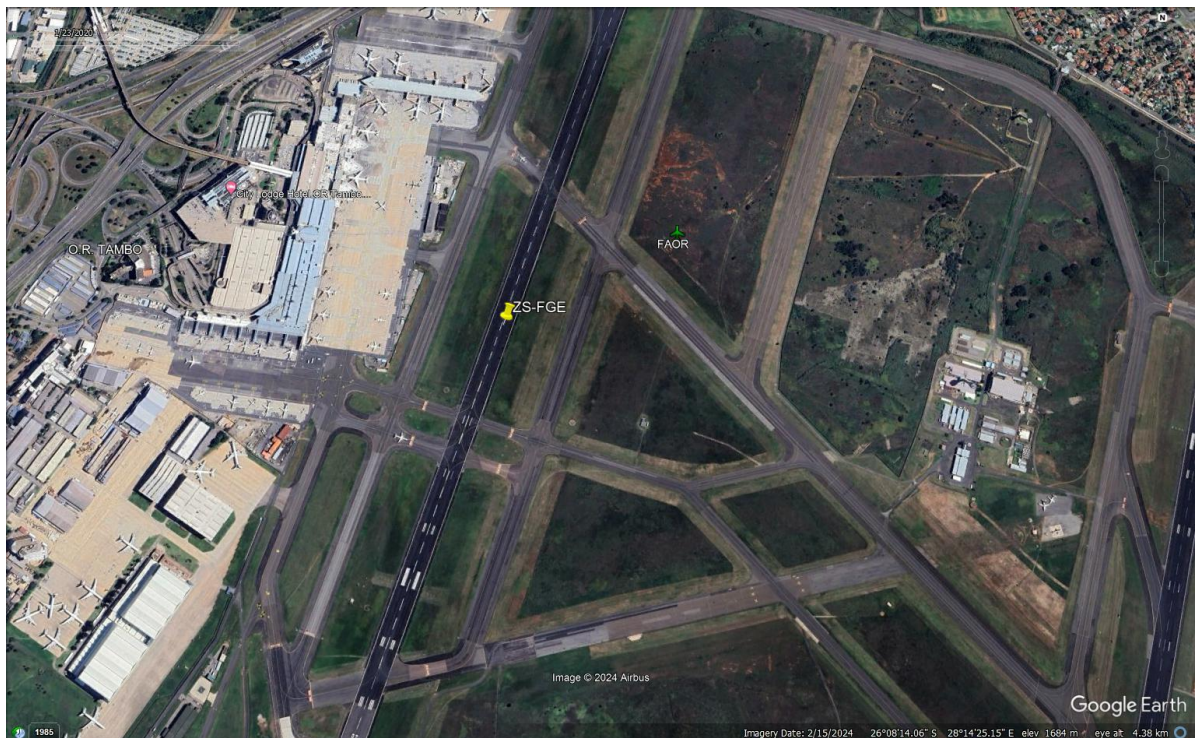


Figure 2: The yellow pin indicates the position where the aircraft came to a stop. (Source: Google Earth)

1.2 Injuries to Persons

Injuries	Pilot	Crew	Pass.	Total On-board	Other
Fatal	-	-	-	-	-
Serious	-	-	-	-	-
Minor	-	-	-	-	-
None	2	4	178	184	-
Total	2	4	178	184	-

Note: Other means people on the ground.

1.3 Damage to Aircraft

- 1.3.1 The left main landing gear outboard spindle sleeve, wheel assembly and brake unit were damaged by the failed wheel hub and bearing. Minor damage was observed on the left-wing inboard flap and inboard ground spoiler which was caused by debris from the left main landing gear inboard tyre that burst during the landing roll.

1.4 Other Damage

- 1.4.1 Minor damage was observed on the runway surface.



Figure 3: Damage caused to the runway surface where the aircraft had stopped.

1.5 Personnel Information

- 1.5.1 Pilot-in-Command (PIC)

Nationality	South African	Gender	Male	Age	32
Licence Type	Airline Transport Pilot Licence				
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instrument, Instructor Grade 2				
Medical Expiry Date	30 September 2024 (Class 1)				
Restrictions	SSL - Special Restriction(s) as Specified OML – Valid only as or with a Qualified Co-Pilot				
Previous Incidents	None				

Note: Previous incidents refer to past serious incidents the pilot was involved in, when relevant to this serious incident.

Flying Experience:

Total Hours	4 667.42
Total Past 90 Days	115.03
Total on Type Past 90 Days	115.03
Total on Type	3 504.36

The PIC had a valid Airline Transport Pilot Licence (ATPL) that was last renewed on 9 September 2023 with an expiry date of 30 September 2024. The PIC had a valid Class 1 medical certificate that was issued on 19 September 2023 with an expiry date of 30 September 2024. The medical certificate was issued with two restrictions: Special Restriction(s) as Specified (SSL), and Valid only as or with a Qualified Co-pilot (OML).

1.5.2 First Officer (FO)

Nationality	South African	Gender	Male	Age	46
Licence Type	Airline Transport Pilot Licence				
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instrument				
Medical Expiry Date	31 July 2024 (Class 1)				
Restrictions	None				
Previous Incidents	None				

Note: Previous incidents refer to past serious incidents the pilot was involved in, when relevant to this serious incident.

Flying Experience:

Total Hours	7 353.5
Total Past 90 Days	193.0
Total on Type Past 90 Days	193.0
Total on Type	771.2

The FO had a valid ATPL which was last renewed on 12 December 2023 with an expiry date of 31 January 2025. The FO had a valid Class 1 medical certificate that was issued on 27 July 2023 with an expiry date of 31 July 2024. The medical certificate was issued with no restrictions.

1.6 Aircraft Information

1.6.1 Boeing 737-800 (Source: www.skybrary.aero)

The Boeing 737-800 is a member of the Boeing 737 family of aircraft. The 737-800 is a stretched version of the 737-700; replaced by the 737-400. It is a narrow-body, fixed-wing aircraft with a tricycle undercarriage and is fitted with two turbofan engines which are mounted under the wings. The 737-800 seats 162 passengers in a two-class layout or 189 in a one-class layout.

Airframe:

Manufacturer/Model	Boeing 737-800	
Serial Number	34269	
Year of Manufacture	2007	
Total Airframe Hours (at time of serious incident)	51 520.2	
Last Inspection (hours & date)	51 504.0	18 April 2024
Airframe Hours Since Last Inspection (A10 Check)	16.2	
CRS Issue date	18 April 2024	
C of A (expiry date)	26 November 2020	30 November 2024
C of R (issue date) (Present Owner)	22 October 2020	
Type of Fuel Used	Jet A1	
Operating Category	Standard Transport Category (Aeroplane)	
Previous Incidents	None	

Note: Previous incidents refer to past serious incidents the aircraft was involved in, when relevant to this serious incident.

Engine No. 1:

Manufacturer/Model	CFM International CFM-56-7B27
Serial Number	895953
Part Number	CFM56-7B26/3
Hours Since New	49 477.0

Engine No. 2:

Manufacturer/Model	CFM International CFM-56-7B27
Serial Number	894950
Part Number	CFM56-7B26/3
Hours Since New	47 480.2

1.6.2 Aircraft History

The aircraft was manufactured in Renton in the United States of America (USA). Its first flight was on 5 October 2007 with a test registration issued number N1786B. The table below shows a breakdown of the aircraft's history, which was mostly operated in South America (12 years).

Airline/Owner	Registration	Date in service
GOL Airlines – Brazil	PR-GTU	22 October 2007
Webjet Linhas Aereas – Brazil	PR-GTU	30 December 2011
GOL Airlines – Brazil	PR-GTU	14 November 2012
Wells Fargo Bank Northwest – USA	N269WC	19 December 2019
FlySafair – South Africa	ZS-FGE	19 October 2020

1.6.3 Left Outboard Mainwheel Hub Assembly and Tyre Information (wheel that separated from the axle)

The two-wheel hubs did not leave the factory as an assembly. The wheel hub halves also had different manufacturing dates; the inner wheel hub had a serial number prefix containing the letter “H”, this type of prefix is only used when individual wheel hub halves are purchased from Honeywell.

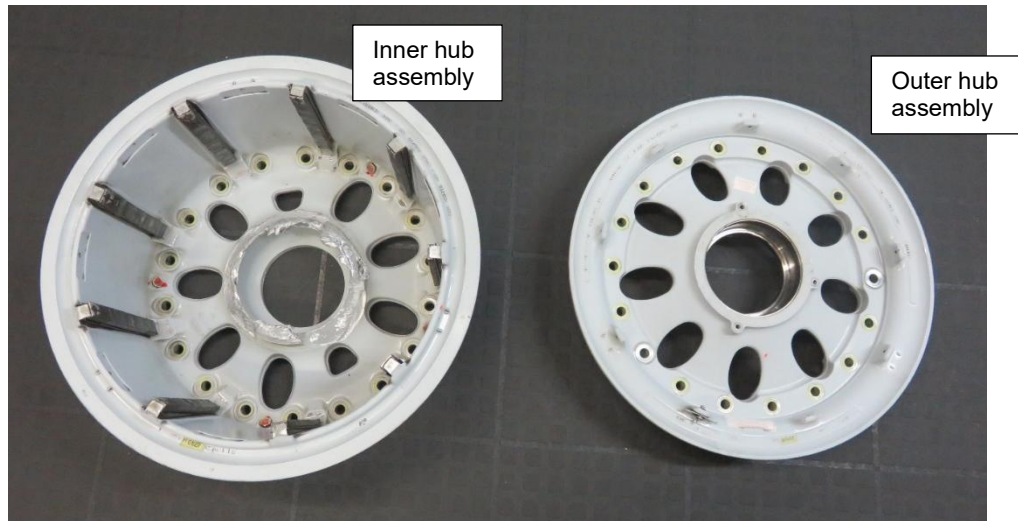


Figure 4: The inner and outer hubs of the mainwheel assembly that separated from the axle.

From the available information, it was determined that the inner and outer main wheel hub assemblies were purchased from a company in Spain and were imported to South Africa in September 2015. The wheel hubs entered the country as used parts with no maintenance history since new; their operational service started after overhaul at a local aircraft maintenance organisation (AMO) with regulatory approval.

The last overhaul was conducted in accordance with the Honeywell Component Maintenance Manual (CMM) 32-40-14 REV 13. According to the list of fitted parts documented on the Authorised Release Certificate (CA 21-19), neither the inner nor the outer bearings were replaced during this overhaul.

The table below contains a summary of the outboard mainwheel that separated from the axle after take-off.

Left Outboard Mainwheel, Outboard Hub Assembly	
Wheel Hub Manufacturer	Honeywell
Manufacturing Date	September 2005
Assy Part Number	2612311-1
Outboard Hub half Part Number	2613128
Outboard Hub half Serial Number	B8561

Last Overhaul Date	13 September 2023
Total Hours Since Overhaul	1 243.1
Total Cycles Since Overhaul	963
Date Fitted to ZS-FGE	6 April 2024
Cycles Since Fitted to ZS-FGE	67
Number of aircraft the mainwheel was fitted to since its last overhaul	6

1.6.4 Left Outboard Mainwheel, Inboard Hub Assembly (wheel that separated from the axle)

The last overhaul was conducted in accordance with the Honeywell CMM 32-40-14 REV 13. According to the list of fitted parts documented on the Authorised Release Certificate (CA 21-19), neither the inner nor the outer bearings were replaced during this overhaul.

The table below contains a summary of the inner mainwheel that remained attached to the axle after take-off.

Left Outboard Mainwheel, Inboard Hub Assembly	
Wheel Hub Manufacturer	Honeywell
Manufacturing Date	January 2010
Assy Part Number	2612311-1
Inboard Hub half Part Number	2615480
Inboard Hub half Serial Number	BH0527
Last Overhaul Date	13 September 2023
Total Hours Since Overhaul	1 243.1
Total Cycles Since Overhaul	963
Date Fitted to ZS-FGE	6 April 2024
Cycles Since Fitted to ZS-FGE	67
The number of aircraft the mainwheel was fitted to since its last overhaul	6

1.6.5 Information of the Tyre Fitted to the Left Outboard Wheel Assembly

Tyre Information	
Tyre Manufacturer	Goodyear
Part Number	441K82T1
Serial Number	91365521
Rethreaded Status	3 times
Last Rethreaded Date	December 2023
Speed Limitation	225 mph (195kt)

1.6.6 Manufacturer Service Bulletin (SB) SB 261311-32-002 and Service Information Letter (SIL) D200904000037

On 11 April 2025, the manufacturer released a Service Bulletin (SB) 261311-32-002 which affected wheel assemblies with Part Number 2612311-1. The SB addressed an operator-reported issue of loosened bearing cup on the inboard wheel hub which led to cup rotation during aircraft operation, and likely to cause hub failure. The SB also introduced the new inboard wheel hub Part Number 2615480 with an improved bearing bore geometry and increased interference fit between the bearing bore and the bearing cup. The SB recommended thermal metal spray repair for dimensional restoration of the old wheel hub Part Number 2612462. The SB contained specific instructions for reidentification of parts repaired; the parts were to be stamped with the letter "R" following the change letter for all wheel hubs with machine Part Number 2612462. This reidentification requirement was only noted in the SB as applicable to wheel hub Part Number 2612462.

After the release of the improved wheel hub with Part Number 2615480, the manufacturer received reports of fatigue cracking initiating at the base of the bearing thrust shoulder of the bearing bore of the wheel hub. This prompted the release of Service Information Letter (SIL) Publication Number D200904000037 on 1 May 2009 which introduced an ultrasonic Non-destructive Testing (NDT) inspection of the wheel hub bearing bore at specified intervals. The requirements of this SIL were incorporated into the manufacturer's Standard Practice Manual (SPM) on 13 May 2013. The manufacturer's Component Maintenance Manual (CMM) required ultrasonic inspection of inboard wheel hub Part Number 2614580 on serial numbers from B H0484 and beyond, at every overhaul.

1.6.7 Extracts Pertinent to Ultrasonic Inspection of the Wheel Hubs
(Source: Honeywell Standard Practices Manual)

- *CAUTION: Repaired hubs may be at greater risk to produce irrelevant indications. After removing damaged material during repair, perform fluorescent penetrant examination of the area of interest (See ASTM E1417). As a minimum, use level II sensitivity penetrant and a dwell time of 30 minutes to verify absence of defects open to surface. After bushing installation or metal spray application, conduct examination per the following instructions to accept /reject repairs producing indication greater than 50 % of the calibration standard reference amplitude.*
- *CAUTION: Proper calibration of the ultrasonic instrument, for shear path distance, is critical for proper evaluation between relevant (E.G Cracks) indication and non-relevant (E.G Inclusions from thermal metal spray).*
- *At the dB level, again optimize signal, retire wheel halves with indications exceeding 50% of FSH of the reference dB level.*

1.7 Meteorological Information

- 1.7.1 The weather information below was obtained from the Meteorological Aerodrome Report (METAR) that was issued by the South African Weather Service (SAWS), recorded at FAOR on 21 April 2024 at 1200Z.

FAOR 211200Z 19005KT 080V250 CAVOK 27/04 Q1024 NOSIG=

Wind Direction	190°	Wind Speed	5kt	Visibility	> 10km
Temperature	27°C	Cloud Cover	Nil	Cloud Base	Nil
Dew Point	4°C	QNH	1024hPa		

1.8 Aids to Navigation

- 1.8.1 The aircraft was equipped with standard navigational equipment as approved by the Regulator (SACAA). There were no records indicating that the navigational equipment was unserviceable before the serious incident.

1.9 Communication

- 1.9.1 The aircraft was equipped with a standard communication system as approved by the Regulator. There were no recorded defects with the communication system before the serious incident.
- 1.9.2 The crew was in constant communication with the ATC personnel for the duration of the flight; they also declared a PAN PAN PAN emergency to the ATC personnel.

1.10 Aerodrome Information

- 1.10.1 The aircraft took off from Runway 21R at FAOR and returned to the same aerodrome after flying a holding pattern to burn fuel; they landed on Runway 21R.

Aerodrome Name	O.R. Tambo International Aerodrome (FAOR)	
Aerodrome Location	Johannesburg, Gauteng	
Aerodrome Status	Licensed	
Aerodrome GPS coordinates	26°08'01.30" South 028°14'32.38" East	
Aerodrome Elevation	5 558ft	
Runway Headings	03L/21R	03R/21L
Dimensions of Runway Used	4 436 x 60m	3 410 x 60m
Heading of Runway Used	21R	

Surface of Runway Used	Asphalt
Approach Facilities	DVOR/DME, ILS LOC, ILS GP, Runway lights, PAPI's
Radio Frequency	ATIS: 126.20, 115.20 Apron: 122.65 Tower East: 118.60 Tower West: 118.10 Approach South: 124.50 Approach East: 124.50 Approach West: 123.70 Surface Movement Control (Ground): 121.90

1.10.2 The FAOR layout chart is attached as Appendix A.

1.11 Flight Recorders

1.11.1 The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR). Both recorders were retrieved from the aircraft after the serious incident.

1.11.2 The FDR was a Honeywell Solid State recorder with Serial Number 13375.

1.11.3 The CVR was a Honeywell Solid State recorder with Serial Number 120-09968 and a recording capability of 2 hours. The aircraft was airborne for more than 2 hours, as a result, the voice recording of the initial communication after the wheel departed the axle after take-off was overwritten.

1.12 Wreckage and Impact Information

1.12.1 The crew performed a normal approach and landing on Runway 21R; during the landing roll, the number 2 wheel on the left main landing gear bogey burst, approximately 30m before the aircraft came to a stop on the runway centreline. The runway surface sustained minor damage because of the missing outer mainwheel and the burst inner tyre which caused the wheel hubs and outboard brake unit on the left main landing gear to contact the runway surface.

1.13 Medical and Pathological Information

1.13.1 Not applicable.

1.14 Fire

1.14.1 There was no pre- or post-impact fire.

1.15 Survival Aspects

1.15.1 No person was injured during the serious incident.

1.16 Tests and Research

1.16.1 Left Main Landing Gear Outboard Wheel Hub Failure

The mainwheel hub assembly that failed during the take-off roll was recovered and sent to a laboratory for examination and analysis to determine the most probable cause of failure. The following was noted as significant findings from the analysis:

- A clear surface layer from thermal metal spray, the metallographic test results found the layer to be composed of 95% aluminium and 5% silicon.
- Clear indications of fatigue fracture with the initiation zone being coincident with the bearing bore radius and the inner surface of the bearing thrust shoulder on the hub (Figure 5).
- Fatigue striations with clear progression directions (Figure 6).
- A build-up of foreign matter and mechanical (burnishing) damage at the initiation zone which suggested that the fracture surface was exposed to operational forces and environment for an undetermined period.
- The smearing damage noted at the edge of fracture surface suggested that the inboard bearing sleeve rotated within the bearing bore after the initiation of the fatigue fracture (Figure 7).
- NDT of the failed inboard hub pieces revealed possible secondary initiated fatigue fracture origins at the transition region between the bearing bore wall and the circumferential radius (Figure 8).

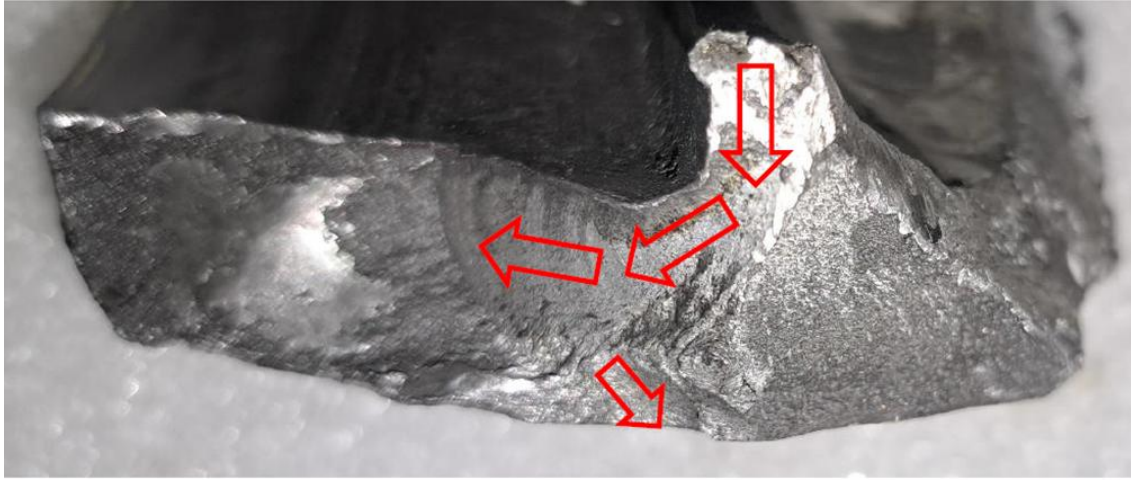


Figure 5: Fatigue crack initiation site at the bearing thrust shoulder.



Figure 6: Fatigue striations with clear progression direction.

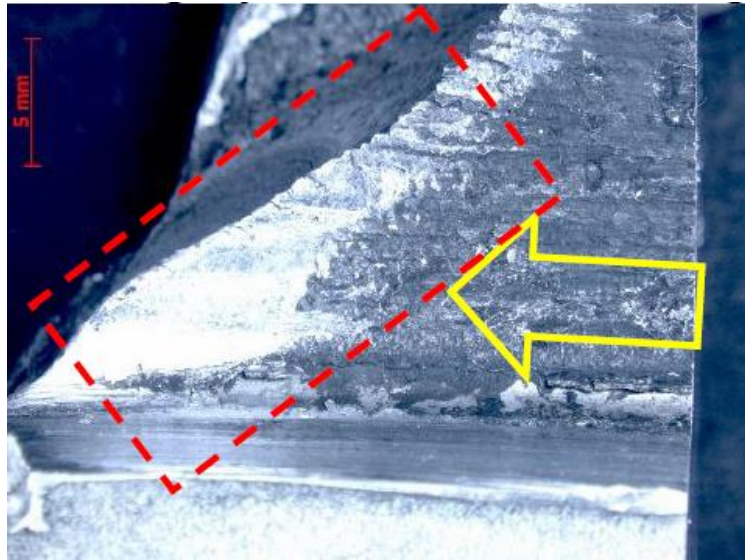


Figure 7: Smearing damage on the bearing bore.

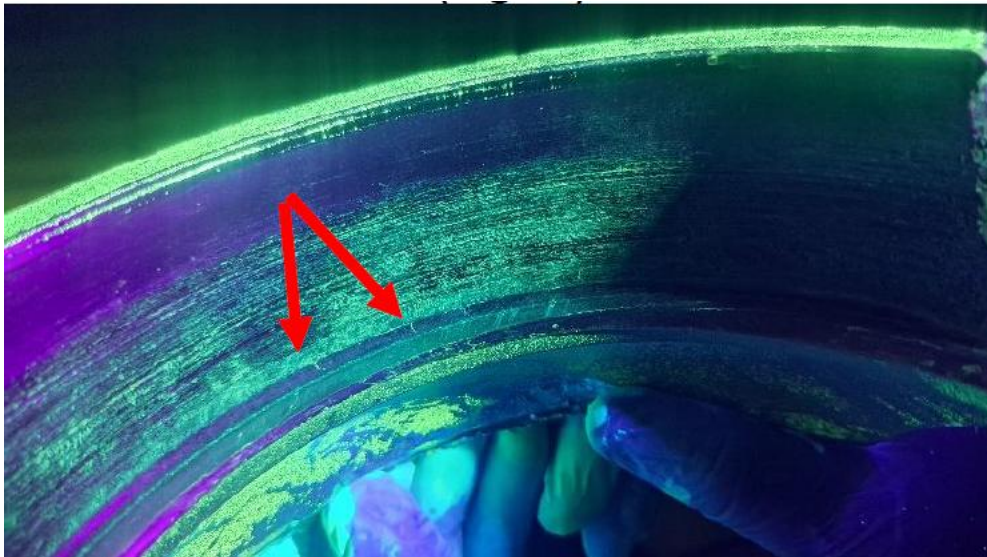


Figure 8: The NDT inspection shows possible secondary initiated fatigue fracture origins.

1.16.2 The inboard wheel bearing and remnants of the outboard bearing were sent to a laboratory for examination and analysis to determine their condition's most probable cause of failure; the following was noted as significant findings from their analysis.

- The inboard cone was still intact and displayed only typical operating conditions such as debris-related indentations and roller scoring. No tempering colours related to excessive heat were visible. The inboard bearing cup was still mounted in a sleeve and was intact. The sleeve outside diameter exhibited minor signs of turning in the hub (Figures 11 and 12).

- The outboard cone was missing the roller complement and most of the cage because of the catastrophic failure. The inner race of the cone showed two clear locations of high heat discolouration as well as a section with no heat effect; these are 180° apart. The inner race showed mechanical damage in the form of roller indentations and scoring. This indicated that the cone had ceased to rotate, and that heat was only generated at the loaded zone on the bottom of the bearing race as mounted (Figures 9 and 10). The pieces of cage recovered from the outboard bearing were small and showed bridge wear and evidence of roller skewing.



Figures 9 and 10: The bottom half of the outboard bearing cone with high heat indications and roller indentations and scoring; and the top half of the outboard bearing cone with no high heat indications and roller indentations and only showing mechanical damage from roller scoring.



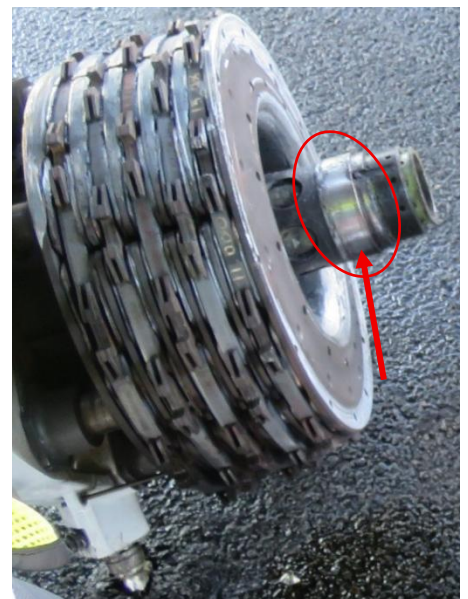
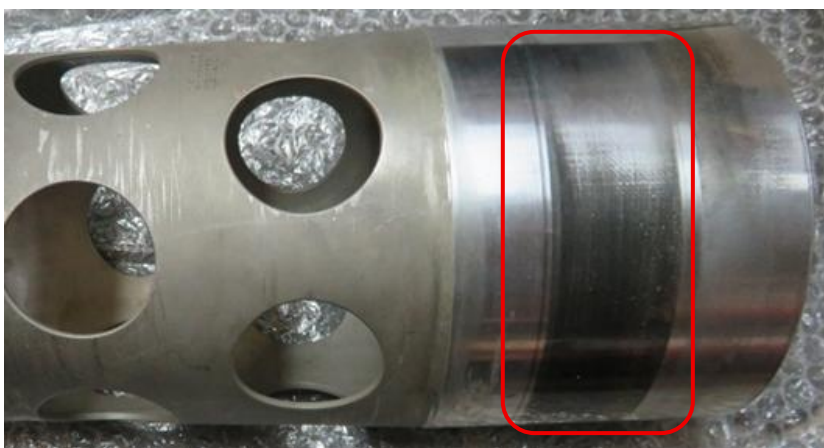
Figures 11 and 12: The inboard with the cone intact (top) and the inboard bearing sleeve with minor rotational scoring (bottom).

1.16.3 Examination of the failed inboard wheel hub and outboard axle of the left main landing gear conducted by the investigator revealed the following:

- Severe galling of the inboard wheel hub brake rotor drive keys with pieces of the failed hub jammed behind brake rotor keys (Figure 13).
- A clear zone of high heat discolouration on the outboard axle sleeve. The zone of heat discolouration was contained to the bottom half of the axle sleeve as mounted on the axle (Figures 14 and 15).



Figure 13: Brake rotor drive key with galling damage and a piece of the failed hub wedged behind it.



Figures 14 and 15: The left main landing gear outboard axle sleeve shows high heat indication localised to the bottom half of the sleeve.

Examination of the brake unit on the left main landing gear by the investigator revealed the following:

- There were large sections of galling damage and material transfer onto the brake unit stators from the liberated pieces of the failed wheel hub (Figure 16).



Figure16: The left main landing gear outboard brake unit shows galling damage and material transfer.

1.17 Organisational and Management Information

- 1.17.1 The operator was issued a Class I Air Service Licence by the Air Service Licensing Council on 26 March 2014 for Category A1 aircraft. The operator was also issued a Class II Air Service Licence on 17 August 2011 for Category A1 aircraft, as well as a Class III Air Service Licence on 17 August 2011 for Category A1 aircraft.
- 1.17.2 The operator had a valid Air Operating Certificate that was issued by the Regulator on 14 April 2023 with an expiry date of 30 April 2024.
- 1.17.3 The aircraft maintenance organisation (AMO) which performed the last maintenance of the aircraft before the serious incident had a valid AMO Certificate that was issued by the Regulator on 22 September 2023 with an expiry date of 31 October 2024.
- 1.17.4 The AMO which performed that last maintenance and overhaul of the wheel hub assembly had a valid AMO Certificate that was renewed on 28 November 2023 with an expiry of 30 November 2024. The AMO was approved for the following categories: A, B and NDT.

1.18 Additional Information

1.18.1 Similar Occurrences

- Source: ATSB TRANSPORT SAFETY REPORT Aviation Occurrence Investigation Final Report AO-2009-062.

The Australian Transport Safety Bureau (ATSB) investigated a similar wheel hub failure that occurred on 20 October 2009, on a Boeing 737-8FE aircraft with registration VH-VUI. Flight crew reported that the aircraft was difficult to taxi, requiring more power and steering input than usual. A subsequent visual inspection revealed the number 4 wheel to be oriented at an angle with respect to the axle, and the disassembly and examination of the wheel revealed that the inner hub had failed from fatigue cracking that had initiated in the area adjacent to the bearing cup. The failed wheel hub was of the same part number as the wheel hub that failed on ZS-FGE, P/N 2615480. The report concluded that the susceptibility to fatigue cracking of the wheel hub design, fatigue crack propagation and the failure to detect fatigue cracks as no ultrasonic inspection was done during the last tyre change; were all contributory factors in the cause of the incident.

- Source: IN-019/2022 Incident on 31 March 2022 involving a Boeing 737-8AS aircraft operated by Ryanair.

While taxiing from the runway to the apron, the left wheel hub on the left main landing gear failed, and the aircraft came to a standstill on the taxiway. It was concluded that the incident was caused by a fracture in the hub of the inner wheel half of the left wheel on the aircraft's left main landing gear due to the propagation of a fatigue crack originating from a corrosion pit. The report also found that the instructions for the major overhaul of the wheel contained in CMM revision 10 (in force on the day of the incident) were not enough to ensure the integrity of the wheel during its service life which is thought to have been a contributing factor. The fractured wheel (P/N 2612311-1 and S/N B13557) was manufactured in 2008.



Figure 17: Hub pieces from IN-019/2022 involving RyanAir aircraft.

1.18.2 Effect of Coatings on Ultrasonic NDT Inspection

(Source: *Ultrasonic Readings Through Coatings*", "*Ultrasonic Readings Through Coatings*, <https://www.onestopndt.com/ndt-articles/ultrasonic-readings-through-coatings>)

Ultrasonic testing is employed for precise thickness measurement and defect detection. Utilising high-frequency sound waves, UT enables the inspection of materials without any structural damage. Coatings on substrates introduce significant complexities to the ultrasonic testing process. Any coatings, be it paint, epoxy, or metallic layers can distort or attenuate ultrasonic signals, leading to challenges in distinguishing between coating and substrate echoes. These interferences make precise measurements difficult to achieve.

Often metallic coatings like zinc or aluminium with higher density cause greater attenuation of ultrasonic waves.

1.18.3 Inboard Bearing Failure (Source: AAIB Bulletin: 11/2020, G-TAWG, AAIB-26323)

Shortly after a normal touchdown, the right outer (No 4) mainwheel separated from its axle and was seen, by the pilots, to pass down the right side of the aircraft. The aircraft vacated the runway and was safely brought to a halt on the taxiway. The wheel separated as a result of a failure of the inboard wheel bearing which led to the failure of the outer bearing. The exact cause of the initial failure to the inboard bearing could not be determined.

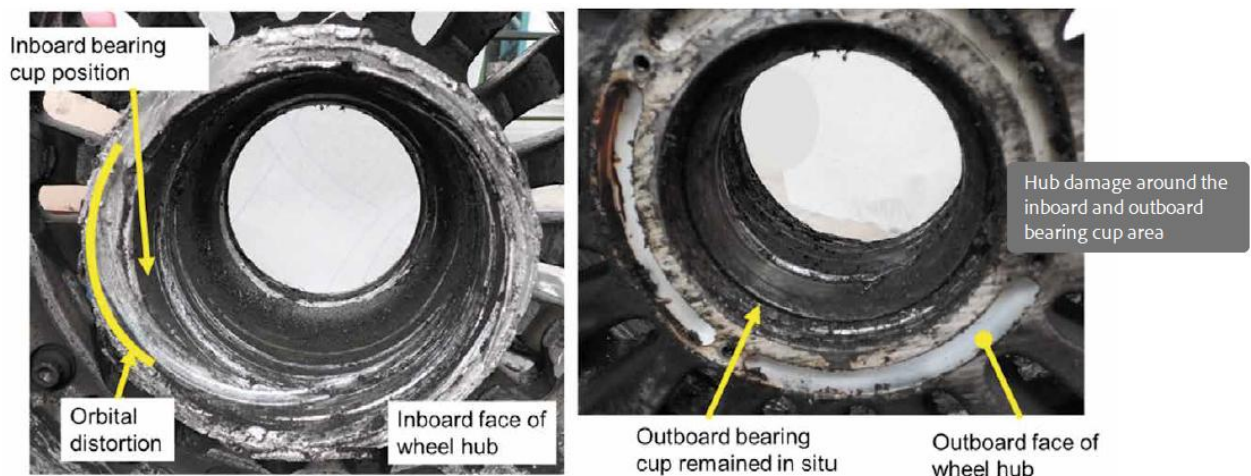


Figure 18: Inboard and outboard wheel hub from AAIB Bulletin: 11/2020 incident

1.19 Useful or Effective Investigation Techniques

1.19.1 None.

2. ANALYSIS

2.1 General

From the available evidence, the following analysis was made with respect to this serious incident. This shall not be read as apportioning blame or liability to any organisation or individual.

2.2 Analysis

2.2.1 Flight Crew

The flight crew was appropriately rated for the aircraft type and operation. The captain (PIC) and first officer had a combined total flying experience of 12020 hours and a combined total of 4275 hours on the aircraft type. Their experience and training were not a factor to the cause of this serious incident.

2.2.2 Operational Procedures

There was neither the official procedure in the QRH nor the FCTM on how to land the aircraft with one main wheel missing. The flight crew's skilful flying on how they landed the aircraft reduced the damage to aircraft as well as mitigated the potential of injury to the passengers.

2.2.3 Air Traffic Control

Following the emergency declaration by the crew, the aircraft was permitted by ATC to enter the hold to burn fuel to reduce its landing weight. The crew was also granted permission to perform a low fly pass above their maintenance facility at FAOR to allow technical personnel to view and assess the damage to the left main landing gear and wheel assembly.

2.2.4 Environment

The weather conditions on the day of the serious incident were fine; the weather had no bearing to the cause of this serious incident.

2.2.5 Machine

- Pieces of the failed inner wheel hub were found jammed behind the brake rotor drive keys, the severe galling of all brake rotor keys, metal transfer on to the brake unit stators and the fact that the pilots had to apply more power than usual during taxi to line up the aircraft on the runway indicated that the inboard hub most likely suffered catastrophic failure during taxi and created a “brake binding” effect that necessitated an increase in power to move the aircraft for line up on the runway.
- The heat discolouration zones identified on the outboard bearing cone and outboard axle sleeve were of the same nature and indicated that it was the lower half of the outboard bearing cone as mounted that suffered all the heat discolouration and roller indentation. The severe heat discolouration and roller indentation localised to the lower half of the bearing as mounted on the axle indicated that at some point during the failure sequence, the outboard bearing was carrying all the load applied to the left side outboard wheel during part of the taxi and, likely, all of the aircraft take-off rolls. The overloading and height rate of rotation of the wheel during take-off resulted in the catastrophic failure of the outboard bearing.

- The layer was found on the inboard hub bearing bore during the SEM analysis with a composition of 95% aluminium and 5% silicon from the metallographic testing. This is a type of thermal metal spray wire that is commonly used for dimensional restoration; there are brand variants that are approved for use in the aviation industry and their specifications are in line with the manufacturer's requirements as stated in the SB 261311-32-002 with a typical hardness of 70-75 HRB. The application of thermal metal spray to the wheel hub was noted in the manufacturer's SPM as an approved repair to restore the dimensions of the bearing bore when bearing cup looseness is found.
- The description of the damage to the inboard bearing cone as being "*typical operating condition*" and the damage of the outside sleeve diameter from rotation in the bearing bore as being "*minor*" indicated that while there was rotation of the inboard bearing in the bearing bore, due to the limited damage inflicted to the outside sleeve diameter, the rotation of the inboard bearing cup was likely consequential because of the hub failure and loss of dimensional interference, and not the direct cause of the hub failure.
- Disintegration of the outboard wheel bearing exposed a cavity large enough to allow the wheel hub to pass freely over the wheel lock nut and shim. Similarly, the cavity formed because of the failed inboard wheel hub allowed the hub to pass freely over the wheel lock nut and shim.

2.2.6 Maintenance

- The lack of maintenance history on the wheel hub halves prior to their entry into operational service in South Africa made it impossible to confirm when the thermal metal spray repair was conducted, whether the repairer was approved to undertake repairs and if the inboard wheel hub did not have a history of fatigue crack indication during overhaul. The locally based AMO that was responsible for overhaul of the hub was not aware of the existence of the repair on the hub bearing bore.
- The available maintenance history of the wheel assembly indicated that all maintenance requirements of the manufacturer were adhered to after entry into service in South Africa. The wheel assembly had ultrasonic NDT inspection conducted at every wheel change. This frequency of inspection exceeded the manufacturer's recommendation of every overhaul.
- It is known that metal coatings have a negative impact on the ability of Ultrasonic NDT testing to accurately identify defects in the coated substrate. The manufacturer's SPM made specific reference to the effect of bearing bore repair on the ultrasonic inspection results and the importance of proper calibration of the equipment on the hub test piece. While evidence indicated that ultrasonic inspection of the hub was done as required, it should be noted that the thermal metal spray layer on the bearing bore in question introduced additional complexity to the inspection process.

- The manufacturer's SB 261311-32-002 required that parts be stamped with the letter "R" following the change letter for all wheel hubs with machine Part Number 2612462 that have received a metal spray repair to comply with the SB. There was, however, no requirement to stamp other wheel hub assemblies to indicate the repair history of the hub with regards to thermal metal spray. Similarly, the manufacturer's SPM did not require the stamping of the wheel hub to indicate repair after thermal metal spray. The manufacturer, however, recommended that a detailed repair history be maintained for each wheel hub assembly. Although the maintenance history recommendation exists, a physical stamp on the wheel hub assembly is far more accessible to all technicians working on the hub and has a permanence that cannot be easily erased or lost. With the understanding that repair processes, specifically thermal metal spray repair, introduce complexity to the ultrasonic inspection process results, it is important to ensure that repairers and inspectors are acutely aware of a wheel hub's history.
- The requirement from the manufacturer to only retire wheel hubs with indications in excess of 50% of the calibrated amplitude of the ultrasonic test equipment meant that wheel hubs with fatigue crack indications below the threshold would be passed as serviceable.
- The NDT equipment, maintenance personnel and maintenance documentation of the locally based AMO which performed the maintenance of the wheel hub in question during its operation in South Africa were scrutinised as part of the investigation. The adequacy of their personnel, equipment, documentation and facilities was found to be satisfactory.

2.2.7 Similar Occurrences

Research into mainwheel assembly failure on Boeing 737-800 aircraft found that it was not a unique occurrence. Reports from various incidents identified two distinctly different failure patterns when bearing failure occurs and when hub failure occurs. Hub failure generally results in the affected hub half breaking down into large pieces and leaving the bearing of that hub half intact, with the other hub half bearing showing damage due to an overload condition and with the bearing bore potentially having orbital damage. Wheel bearing failure generally results in substantial damage to the bearing of both the inner and outer hubs as one bearing fails completely and the other experiences damage from the resulting overload condition. One or both bearing bores would also exhibit orbital distortion. The wheel assembly failure pattern on ZS-FGE was congruent to the hub failure pattern identified from similar occurrence reports that were reviewed.

3. CONCLUSION

3.1 General

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

To serve the objective of this investigation, the following sections are included in the conclusion heading:

- **Findings** — are statements of all significant conditions, events, or circumstances in this serious incident. The findings are significant steps in this incident sequence, but they are not always causal or indicate deficiencies.
- **Causes** — are actions, omissions, events, conditions, or a combination thereof, that led to this serious incident.
- **Contributing factors** — are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the serious incident occurring, or would have mitigated the severity of the consequences of the serious incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2 Findings

- 3.2.1 The pilot-in-command (PIC) had a valid Airline Transport Pilot Licence (ATPL) that was last renewed on 9 September 2023 with an expiry date of 30 September 2024. The PIC had a valid Class 1 medical certificate that was issued on 19 September 2023 with an expiry date of 30 September 2024. The medical certificate was issued with two restrictions: Special Restriction(s) as Specified (SSL), and Valid only as or with a Qualified Co-pilot (OML).
- 3.2.2 The first officer (FO) had a valid ATPL which was last renewed on 12 December 2023 with an expiry date of 31 January 2025. The FO had a valid Class 1 medical certificate that was issued on 27 July 2023 with an expiry date of 31 July 2024. The medical certificate was issued with no restrictions.
- 3.2.3 The maintenance records available indicated that the wheel assembly was maintained in accordance with the manufacturer's requirements.
- 3.2.4 The weather conditions on the day had no bearing to the cause of the serious incident.
- 3.2.5 The failure of the inboard wheel hub took place over an undetermined period which involved high cyclic load of the wheel.

- 3.2.6 The inboard wheel hub likely suffered catastrophic failure while the aircraft taxied for take-off and not during the take-off roll on the day of the serious incident.
- 3.2.7 The maintenance history of the wheel was incomplete and did not disclose the nature of the discrepancy that required thermal metal spray. From the maintenance records made available to the investigators, it was concluded that the most recent maintenance of the wheel was in accordance with the manufacturer's recommendations.
- 3.2.8 The outboard bearing suffered extensive damage than the inboard bearing, with clear indications of high heat exposure and severe roller indentation, all of which was contained to the lower half of the bearing as mounted on the axle. This indicated that the outboard bearing likely carried most of the wheel load during the final stage of taxi and the entire take-off roll.
- 3.2.9 Metallurgical analysis indicated that the fatigue fracture existed before rotation of the bearing cup. This was evidence that the rotation of the bearing cup was consequential in the failure sequence of events.

3.3 Probable Cause

- 3.3.1 The failed wheel hub components indicated that the likely cause of the wheel hub failure was due to a fatigue crack that initiated at the bearing cup seat transition of the wheel inboard hub bearing bore.

3.3.2 Failure Sequence of Events

- The fatigue crack initiated at the bearing cup seat transition of the wheel inboard hub half bearing bore.
- The fatigue crack caused loss of interference fit between the inboard bearing cup and the bearing bore, allowing the bearing cup to rotate. The rotation of the bearing cup exacerbated the crack and failure of the hub with fretting and additional heat generation which allowed the crack to propagate at a rapid rate.
- The inboard hub half bearing bore failed catastrophically with the separated pieces of the hub jamming in the brake unit and causing a binding effect.
- The failed inboard hub forced the outboard bearing to carry all the load on the wheel, creating a severe overload condition and improper loading of the bearing due to misalignment of the wheel on the axle. The stress was concentrated on the lower half of the bearing.
- The outboard bearing suffered catastrophic failure and disintegrated at some point during the final stage of taxi or the early parts of the take-off roll. The weight of the aircraft on the outboard bearing cavity was the only force keeping the wheel on the axle. When the aircraft rotated for take-off, the wheel was unloaded and continued to wobble and spin on the axle until it separated.

3.4 Contributory Factor/s

3.4.1 Bearing cup seat transition.

4. SAFETY RECOMMENDATIONS

4.1 General

The safety recommendations listed in this report are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation and are based on the conclusions listed in heading 3 of this report. The AIID expects that all safety issues identified by the investigation are addressed by the receiving States and organisations.

4.2 Safety Message

4.2.1 Operators are to ensure that all purchased spares have a known maintenance, repair and status records. Maintenance history and repair status play a vital part in component maintenance and affect the decision-making processes with regards to defect acceptance or rejection, as well as the level of inspection and scrutiny a component is subjected to during maintenance.

4.3 Safety Recommendation

4.3.1 The Director of Civil Aviation should issue an advisory notice to all type operators indicating that for ultrasonic testing performed on Boeing 737–800 main wheel assemblies, details of indications that do not meet the manufacturers' threshold for hub retirement be noted for future reference as a means to find defect propagation.

5. APPENDICES

5.1 Appendix A: FAOR Aerodrome Chart

This report is issued by:

**Accident and Incident Investigations Division
South African Civil Aviation Authority
Republic of South Africa**

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