# LIMITED OCCURRENCE INVESTIGATION REPORT – FINAL

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reference Number** | CA18/3/2/1424 | | | | | | | | | | |
| **Classification** | Serious Incident | | **Date** | 7 August 2023 | | | **Time** | 1230Z | | | |
| **Type of Operation** | Air Transport Operations Carriage (less than 20 passengers) – Part 135 | | | | | | | | | | |
| **Location** | | | | | | | | | | | |
| Place of Departure | Arathusa Safari Lodge (FAAR) Airstrip, Mpumalanga Province | | | Place of Intended Landing | | | Mala Mala Airfield (FAMD), Mpumalanga Province | | | | |
| Place of Occurrence | Mala Mala Airfield (FAMD) | | | | | | | | | | |
| GPS Co-ordinates | Latitude | 24º48'39.83" S | | Longitude | 031º32'19.78" E | | Elevation | 1 070 feet | | | |
| **Aircraft Information** | | | | | | | | | | | |
| Registration | ZS-JEM | | | | | | | | | | |
| Make; Model; S/N | Cessna Aircraft Company; 208B (Serial Number: 208B-0912) | | | | | | | | | | |
| Damage to Aircraft | Minor | | | Total Aircraft Hours | 15 762.16 | | | | | | |
| **Pilot-in-command** | | | | | | | | | | | |
| Licence Type | Commercial Pilot Licence (CPL) | | | Gender | Male | | Age | 27 | | | |
| Licence Valid | Yes | Total Hours | | 2 009.3 | Total Hours on Type | | | 479.7 | | | |
| Total Hours 30 Days | 60.8 | | | Total Flying on Type Past 90 Days | 182.4 | | | | | | |
| **People On-board** | 2+7 | **Injuries** | 0 | **Fatalities** | 0 | **Other (on ground)** | 0 | | | | |

**What Happened**

On Monday, 7 August 2023, two pilots and seven passengers on-board a Cessna 208B with registration ZS-JEM took off on a flight from Arathusa Safari Lodge Airstrip (FAAR) in Mpumalanga province to Mala Mala Airstrip (FAMD) in the same province. The distance between FAAR and FAMD is approximately 5 nautical miles (nm). Visual meteorological conditions (VMC) by day prevailed at the time of the flight which was conducted under the provisions of Part 135 of the Civil Aviation Regulations (CAR) 2011 as amended.

The pilot-in-command (PIC) was the pilot monitoring (PM) and the first officer (FO) was the pilot flying (PF) the sector. According to the crew, they were on their ninth sector for the day, with four more sectors to go. No anomalies were noticed during the inspection checks that were conducted between flights at FAAR. During the ninth sector at FAMD, the crew joined right downwind for Runway 34. All required radio communications were made, and Mala Mala Airfield ground crew was contacted on very high frequency (VHF) 122.25-Megahertz (MHz) approximately two minutes before landing.

The aircraft was configured for landing with full flaps selected down and at an approach speed of 85 knots (kts). The FO transitioned the power to idle during flare, whereafter, the aircraft floated for a short distance and landed about three to four centreline paintings down the runway. The aircraft touched down with the left landing gear, followed by the right landing gear and the nose wheel. As the nose wheel contacted the runway, the FO applied full reverse thrust and equal brakes. The aircraft veered off to the left of the centreline and the FO assumed it was loss of directional control. The FO attempted to correct the direction by applying full right rudder but noticed that the aircraft was not decelerating as expected; instead, it was rolling much faster on the runway.

The PIC called “brake hard”, to which the FO replied that both brakes were hard. The crew suspected a possible brake failure after the FO had called out “I have no brakes”. The PIC took control of the aircraft and attempted to steer it back to the centreline by applying the right rudder and right brake. At this point, the PIC

noticed that there was no brake effect on the right wheel. He stated that they considered re-activating the reverse thrust but realised that it would not make a difference because the aircraft was travelling at a slow speed of approximately 25 kts, therefore, this action would not be effective. At this stage, the remaining runway surface was about 50 metres (m). The crew decided to shut down the engine to eliminate the idle thrust energy (which plays a role in the process of slowing down the aircraft).

Thereafter, the PIC asked the FO to command cabin safety to passengers as he was about to brake on the clearway at the end of the runway. The FO noticed that the aircraft was about to overshoot the runway as it headed for the shrubs; therefore, he instructed the passengers to remain seated. The PIC applied the right rudder pedal and the left wheel brake simultaneously to steer the aircraft in a straight line and to slow it down. The aircraft came to a stop approximately 180m beyond the threshold of Runway 16. The FO disembarked from the aircraft first to ensure that there was no immediate danger (wild animals, and so forth). After the PIC was satisfied that there was no eminent danger, the FO asked the occupants on-board to carefully disembark from the aircraft.

According to the PIC, the runway is an upslope when landing on Runway 34. He stated that the aircraft's regulated 92% maximum take-off weight (MTOW) made it difficult to bring the aircraft to a stop. The PIC stated that he steered the aircraft 90º to avoid impacting the shrubs and trees.

After seeking help from the fire-fighting personnel and game rangers, the passengers and their luggage were transported in the game ranger's vehicle to a safe place at the lodge. The crew conducted further inspection on the aircraft, and they noticed skid marks on the left wheel. As they went around to the right wheel to inspect it, they noticed brake fluid seeping from the bottom part of the right brake calliper.

**Figure 1:** The aircraft as it came to rest. (Source: PIC)


**Figure 2:** Aerial view of the threshold of Runway 16 and ZS-JEM's resting position. (Source: Operator)


**Figure 3:** A snapshot taken from the video footage. It shows the brake fluid leaking from the brake calliper, and evidence of brake fluid on the tyre. (Source: PIC)

Post-incident Investigation:

A review of the maintenance records (airframe, propeller and engine logbooks) was conducted. According to available information, on 6 June 2023, maintenance relating to the brake system was conducted with a job card number 091 for the right wheel brake calliper; O-rings were replaced during this maintenance. The task was accomplished by bleeding the brakes. The maintenance work was signed off following an inspection.

Records showed that an advisory Service Bulletin SB7105 was released on 15 May 2014 by the aircraft type brake manufacturer. The SB related to product improvement applicable to Part 30-182 brake assemblies which were fitted on the aircraft at the time of the incident.

**The Service Bulletin**

***Reason:*** *A complete design of a new brake lining, 066-15300 that offers brake lining life. Brake lining 066-15300 is thicker with more wearable friction material than existing lining. These is sufficient running clearance in existing brake frame designed to fit 066-15300 linings.*

***Description:*** *Lining P/N 066-03300 used in the P/N 30-182 brake assembly is superseded by P/N 066-15300 used in the P/N 30-182A break assembly.*

***Caution:*** *Lining must be used in complete set on each brake assembly. The 066-15300 lining is 0.035 inch thicker than the 066-03300 lining.*

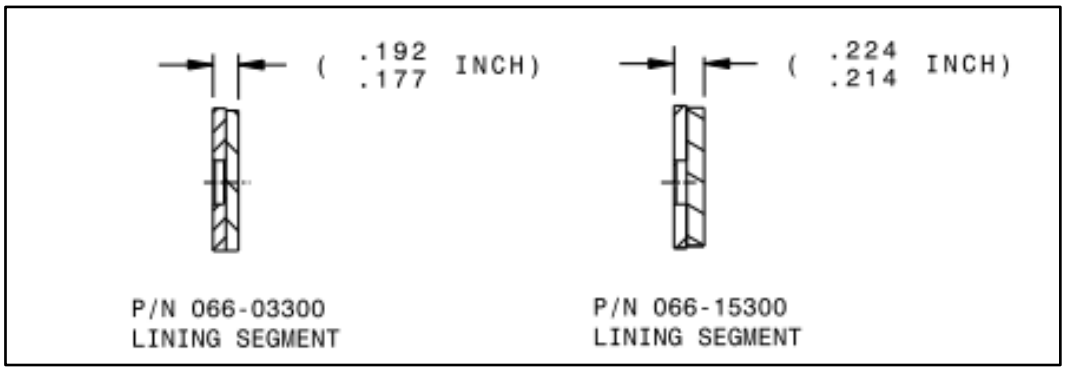


**Figure 4:** Difference in brake lining.

**Compliance:**

*Recommended-at time of overhaul. The SB was approved for support of an FAA TSO-C26 product. It is not mandatory but advisory for operators' consideration.*

The investigation found that the daily scheduled 13 sector flights are conducted within a 40 nm radius with most airfields located in proximity to each other, and range about 12 nautical miles. The longest range is 40 nm. Moreover, the airfields conditions differ, with some runways covered in gravel and grass, and others in asphalt. In addition, some runways are short, whilst others have sufficient length. It should be noted that the runway at FAMD was sufficient during this incident, with a total length of approximately 1308 metres (m) and a width of 23m. *Figure 5 shows all 13 daily scheduled sectors for ZS-JEM within a 40 nm radius.*

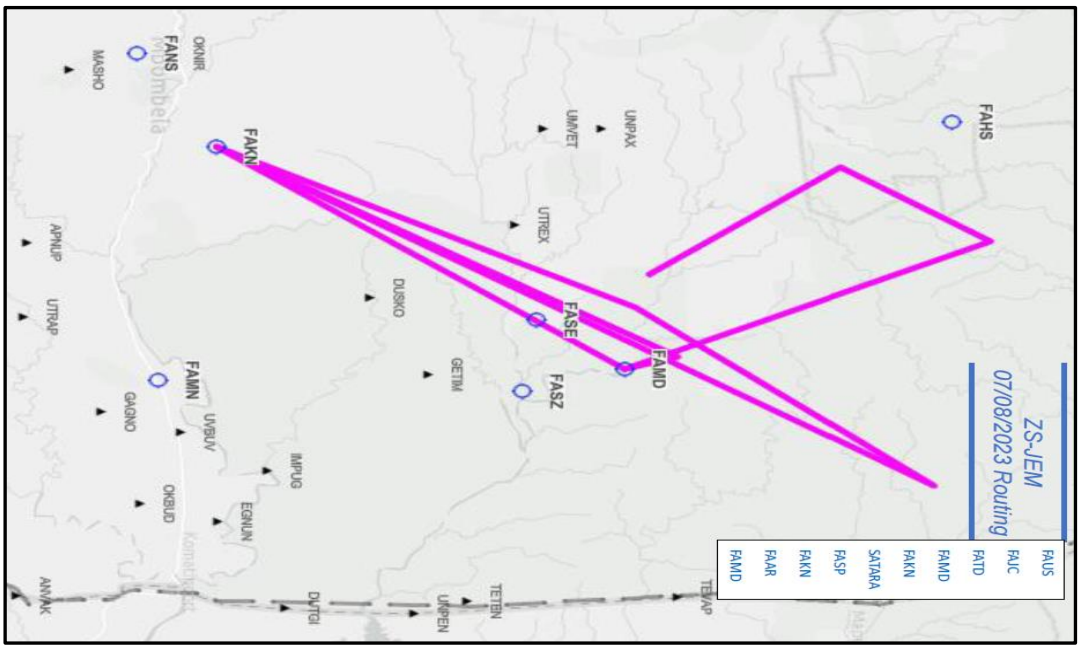


**Figure 5:** The aircraft's daily 13 sectors route.

**Post-incident Inspection:**

The right brake calliper was removed from the aircraft and disassembled at an approved aircraft maintenance organisation (AMO) to determine the cause of the hydraulic leak.


**Figure 6:** The brake calliper components with numbers pointing to the brake cylinder pistons.

**Figure 7:** Brake calliper's third piston and the O-ring.

The brake linings were found to be within limits; they measured 0.13 inches (inch). During disassembly, it was found that the Number 3-cylinder O-ring was damaged. Although other O-rings had evidence of hardness condition which could be related to brake heat generated during the operation of the aircraft over a lengthy period, only the Number 3-cylinder O-ring was damaged. The O-ring had peeled off, which indicated damage that could be attributed to high friction whilst engaging brake mechanism. It was also noted that the O-ring calliper was changed in the last maintenance inspection on the aircraft on 15 June 2023 prior to the incident. The Number 3 brake calliper O-ring was likely damaged during operation, which could also be associated with excessive heat generated during brake application. The Number 3 piston displayed signs of overheating and had traces of thick black hydraulic fluid film around it.

The O-rings are treated as on condition items; this means that they are only changed if there is a requirement such as if leaks are observed during inspection. According to the aircraft maintenance manual, the components are usually inspected during the 200-hour airframe inspection or the annual inspection.

**Laboratory for Microscopy and Micro Analysis Report:**

The information below is an extract from the laboratory tests report conducted after the inspection of the failed O-ring:

*A set of used O-rings, part number MS-28775-224 originating from the brake assembly of a Cessna Grand Caravan 208B with registration ZS-JEM were received to determine the most probable cause causational factors towards the note damages. The reference O-ring was supplied. The total operational hours exposure of the failed O-ring was not disclosed during this submission.*


**Figure 8**: Four submitted O-rings (left) and a reference O-ring (new) on the right.

***Background Information: Properties of Nitrile Rubber***

*Nitrile rubber, also known as NBR (Nitrile Butadiene Rubber), is a commonly used elastomer that resists various fluids (oil and fuels). However, its performance can be affected by temperature exposure. The effect of temperature on nitrile rubber O-rings can be summarized as follows.*

- *Low temperatures (cold environments): Nitrile rubber becomes less flexible and more rigid at low temperatures. This reduced flexibility can lead to issues like decreased sealing effectiveness, increased risk of cracking, and even loss of elasticity.*
- *High temperatures (hot environments): Nitrile rubber has a temperature limit beyond which it starts to degrade. These limits are generally around 200ºFerenheit and 250ºF (93ºC-121ºC) degree Celsius for continuous use, but it can vary depending on the specific formulation and additives used in the rubber. As temperatures increase, the rubber may lose its elasticity and become softer, leading to reduced sealing efficiency.*
- *Thermal degradation resulting in hardening, cracking and loss of mechanical properties is due to prolonged temperature exposure during operation.*
- *Chemical interactions with certain fluids or gases can occur more readily at elevated temperatures, potentially causing the rubber to swell, deform or degrade.*
- *Thermal expansions: Nitrile rubber, like most materials, expands when heated and contacts when cooled. This thermal expansion and contraction could affect the dimensions and sealing capabilities of O-rings, particularly in precision applications.*

- *Thermal cycling: Repeated exposure to fluctuating temperatures (thermal cycling) can accelerate the degradation of nitrile rubber. The expansion and contraction cycles can cause microcracks to form, promoting premature failure of the O-rings.*

***Background information: Installation of Rubber O-rings.***

*Common fitment mistakes during the installation of rubber O-rings:*

- *Incorrect O-ring specification for the application.*
- *Improper lubrication (where applicable).*
- *O-ring surface damage during installation; nicks, cuts or abrasions.*
- *Overstretching or twisting of the O-ring resulting in distortion and deformation.*
- *Improper or damaged gland/grooves: the groove or gland into which the O-ring is seated must be un-damaged and /or clean to accommodate the O-ring's dimensions.*
- *Uneven or inadequate compression.*
- *Incorrect seating: improper seating within the groove may lead to pinching.*

***Tests:***

*The apparatus employed for these tests are Stereo-Microscopes and Digital Camera. The methodology included the visual examination of supplied parts followed by a Light-Microscope investigation.*

*Low Magnification Inspection Results:*

*The visual inspection revealed a single O-ring with a tear within the inner circumference (Refer to Figure 9).*

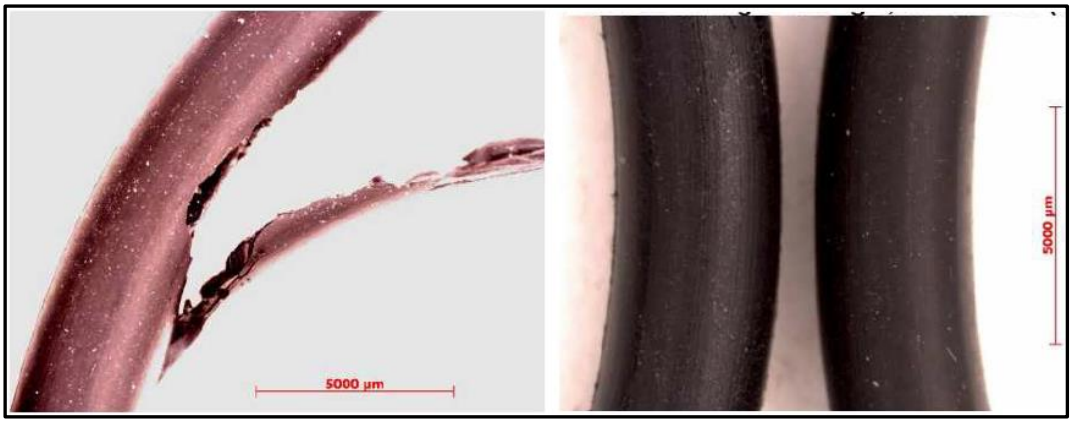


**Figure 9:** Damaged O-ring (left) and a comparison of new and used O-ring surfaces (right).

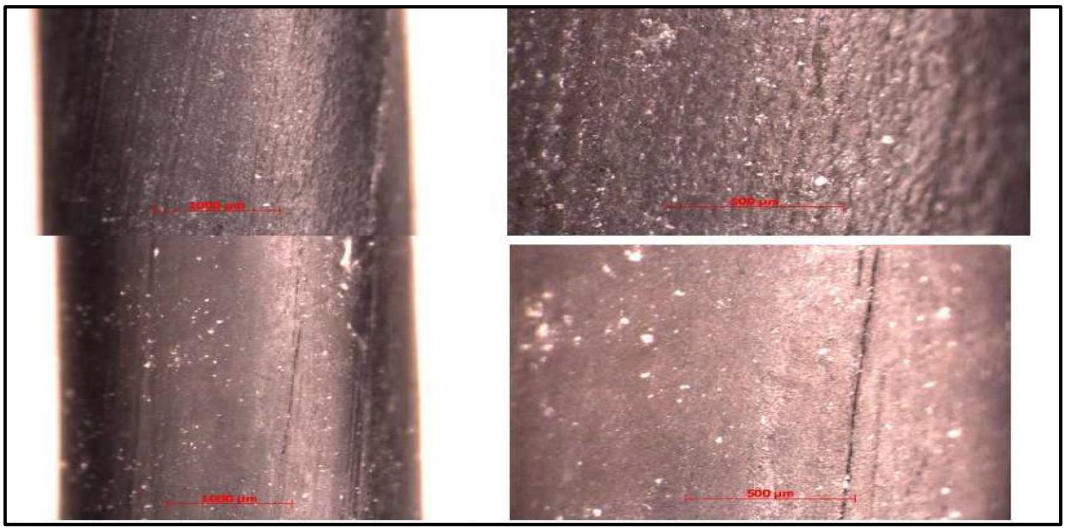


**Figure 10:** New (top) vs used (bottom) surfaces morphologies (stereo).

*Surface imprints were noted on O-ring 2.*

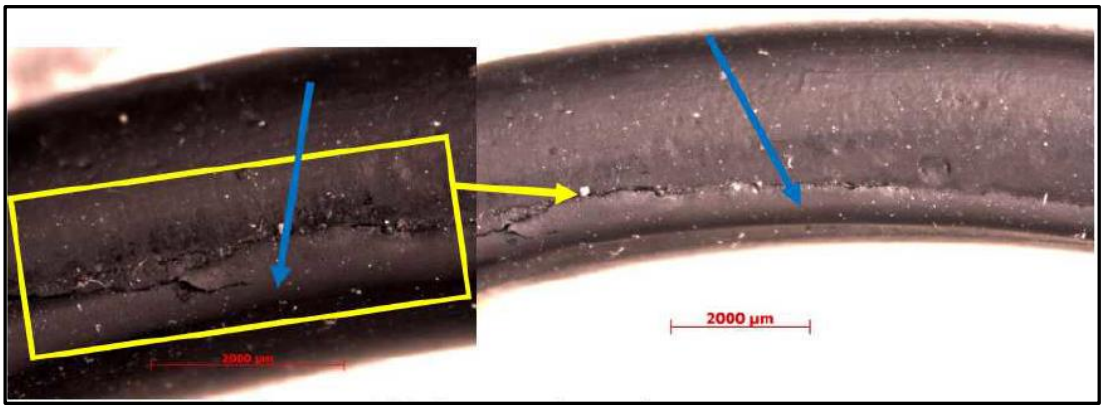


**Figure 11:** Fractured initiation zone (stereo).

***Other Results:***

*The shore hardness tests revealed an average increase of ±26% between the new and used O-rings. This is indicative of exposure to operational time (a function of operating temperature variations, type of fluids and pressure) and total time since manufacture (natural ageing; a function of material composition, storage conditions etc.).*

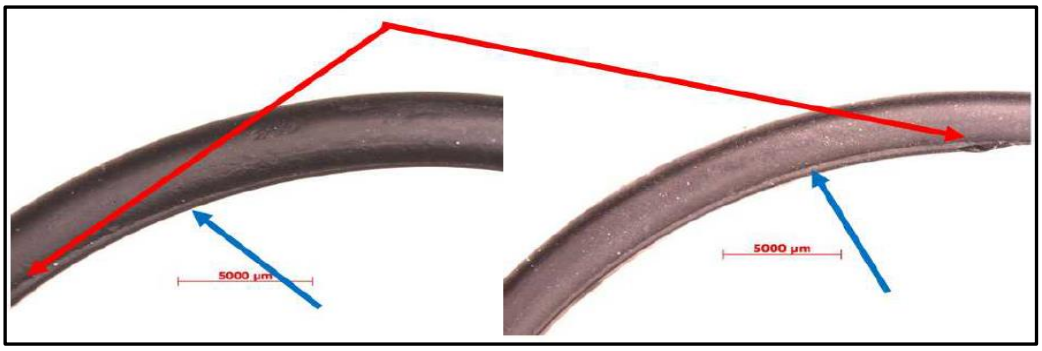


**Figure 12:** O-ring fracture initiating zone and lipped area (stereo).

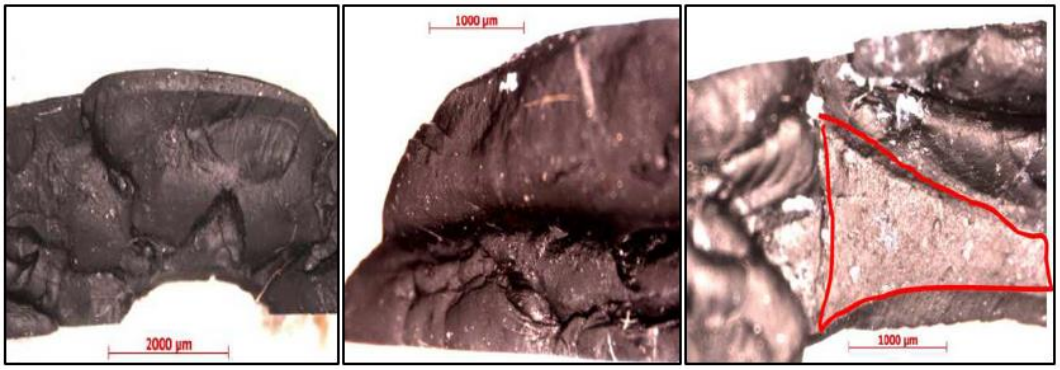


**Figure 13:** Three stages of fracture surface morphology (stereo).

*A slight increase in the average outside diameters was noted. This is expected and indicative of applied pressure during fitment*.

| Hardness and Dimensional Test Results | | | | | |
|---|---|---|---|---|---|
| | Shore Hardness A | | | | |
| Test Run | Ref. | O-ring 1 (fract) | O-ring 2 | O-ring 3 | O-ring 4 |
| *Test 1* | *66.8* | *73.1* | *76.7* | *85.1* | *83.8* |
| *Test 2* | *65.7* | *73.6* | *73.2* | *83.4* | *82.4* |
| *Test 3* | *67.9* | *71.8* | *73.1* | *83.9* | *84.9* |
| **Average** | **66.8** | **72.8** | **74.3** | **84.1** | **83.7** |
| **OD (mm)** | 3.46 | 3.52 | 3.52 | 3.59 | 3.56 |

**Table 1:** Shore hardness and dimension results.

*Discussion and conclusion*

*The conclusions are based on the investigation obtained from the supplied parts/components and information only.*

- *The used O-ring revealed a fracture (tear) to a single unit and some indications of surface imprints.*
- *The new and used O-rings compared favourably under the unloaded and loaded tests (ASTM D1414) with no clear transverse cracking.*
- *The used O-ring revealed no clear indications of exceedingly high temperature exposure/s.*
- *The fractured O-ring revealed clear indications of pinching corresponding with the initio on location of the fracture (tear). This could be attributed to incorrect fitment.*
- *The shore A hardness and dimensional test results compared favourably to the expected NBR O-rings exposed to a period of operation. However, the exact period of operation was not disclosed to this investigation.*

**Aircraft Performance General Information (with cargo pod)**

| | |
|---|---|
| LANDING PERFORMANCE: | |
| Ground Roll | 710 FT |
| Total Distance Over 50 FT Obstacle | 1600 FT |
| STALL SPEED (KCAS): | |
| Flaps Up, Idle Power | 75 KNOTS |
| Flaps Down, Idle Power | 61 KNOTS |
| MAXIMUM WEIGHT: | |
| Ramp | 8035 LBS |
| Takeoff | 8000 LBS |
| Landing | 7800 LBS |
| * Speeds are based on mid-cruise weight. | |

**Table 2:** Shows the landing chart for aircraft performance required landing distance.

According to the Pilot's Operating Handbook, the required landing distance with the cargo pod installed at a maximum allowable weight of 7800 pounds (lbs) is 1600 ft (487.7m) total distance over a 50 ft obstacle, and 710 ft (216.408m) ground roll distance. The aircraft was at 92% MTOW, and at approximately 7176 lbs at the time of landing, which was within limits. Also, there was sufficient fuel remaining in the aircraft tanks, which was approximately 1270 lbs.

**The Aerodrome**

According to available information, FAMD is licensed. The runway orientation is 16/34, and is 1 308m long and 23m wide. It has an apron area where aircraft could park for passengers to embark or disembark, and to load and off-load cargo. The runway and apron are covered in asphalt. There is no fence around the FAMD and animals roam freely. Rangers ensure that the runway is clear of animals before aircraft could land or take-off. On the day of the flight, the crew opted to land on Runway 34, which has a slight upslope. The aircraft, with 92% maximum take-off weight, had sufficient runway to execute a safe landing at FAMD.

**Findings**

Personnel Information

1.1. The PIC had a valid Commercial Pilot Licence (CPL) that was initially issued by the Regulator (SACAA) on 13 October 2016. His licence renewal was issued on 5 January 2023 with an expiry date of 31 December 2023. The PIC had a Class 1 aviation medical certificate that was issued on 13 September 2022 with an expiry date of 30 September 2023. The aircraft type was endorsed on his licence.

1.2. The FO had a CPL that was issued initially by the Regulator on 8 July 2022. Her licence renewal was issued on 9 May 2023 with an expiry date of 30 June 2024. The FO's Class 2 aviation medical certificate was issued on 12 August 2019 with an expiry date of 31 August 2024. The aircraft was endorsed on her licence.

Aircraft Information

1.3. The aircraft was issued a Certificate of Airworthiness (C of A) by the Regulator on 15 May 2023 with an expiry date of 31 July 2024.

1.4. The last maintenance inspection on the aircraft prior to the incident flight was conducted and certified on 15 June 2023 at 15 586.57 airframe hours. The AMO issued a Certificate of Release to Service (CRS) with an expiry date of 15 June 2024 or at 15 786.57 hours, whichever comes first. The aircraft was flown a total of 175.59 hours at the time of the incident. The aircraft had a total of 15 762.16 airframe hours.

1.5. The AMO that conducted maintenance inspection on the aircraft had a Regulator-approved AMO certificated that was issued on 30 January 2023 with an expiry date of 28 February 2024.

1.6. The operator had an approved Air Operating Certificate (AOC) that was issued by the Regulator on 12 June 2023 with an expiry date of 30 June 2024. According to the operator's operational specifications dated 12 June 2023, the aircraft was endorsed and certified to operate under the provisions of Part 135.

1.7. The aircraft's right landing gear wheel brake calliper O-ring was found damaged, probably due to pinching during fitment. Although the Number 3 piston O-ring was pinched during fitment, there was no evidence of fluid leak on the Number 3 piston area. The only leak observed was on the right calliper bleed valve.

1.8. No leaks were observed on the right and left callipers during the pre-flight inspections between flights and after flight inspections post maintenance, which was conducted on 6 June 2023. The aircraft was flown for 175.59 airframe hours, which included take-offs and landings since the maintenance on the callipers on 6 June 2023.

The Aerodrome

1.9. The runway orientation at FAMD is 16/34, and is 1 308m long and 23m wide. It has an apron area where aircraft could park. The runway and apron are covered in asphalt. There is no fence around FAMD and the animals roam freely on the runway and the apron area. Rangers ensure that the runway is clear of animals before aircraft could land or take-off. The crew opted to land on Runway 34, which has a slight upslope.

1.10. The FO landed the aircraft deep and, during the landing roll whilst attempting to reduce speed by applying brakes and reverse thrust, the right main landing gear wheel brake failed. This prevented the crew from bringing the aircraft to a safe stop on the runway.

Weather Conditions

1.11. Fine weather conditions prevailed at the time of the flight as reported by the crew on the form number CA 12-03. The weather conditions were as follows:
Wind Direction: 160º, Wind Speed: 5kts; Visibility: 9999; Temperature: 22ºC; Cloud Cover: CAVOK

1.12. The aircraft's weight and balance were within limits at the time of the flight; there was sufficient fuel in the fuel tanks.

**Probable Cause**

The aircraft's speed was high which resulted in the aircraft floating during a flare, followed by a deep landing. The aircraft veered off to the left of the centreline and overshot the runway by 180m before it came to a stop. The cause was attributed to the right calliper bleed valve leak which resulted in the drop in brake pressure on the right, and which caused the aircraft to veer off to the left of the centreline.

**Contributing Factor(s)**

None.

**Safety Actions**

The operator has, since this incident, embarked on upgrading all its fleet brake assembly units as advised in the manufacturer's Service Bulletin 7105, as well as implemented measures to monitor the O-ring's durability during operations.

**Safety Message**

Maintenance crew and AMOs should develop procedures that will ensure that the brake calliper O-rings are fitted correctly to prevent possible leaks and brake failure during operations.

**About this Report**

*The decision to conduct a limited investigation is based on factors including whether the cause is known and the evidence supporting the cause is clear, the level of safety benefit likely to be obtained from an investigation and that will determine the scope of an investigation. For this occurrence, a limited investigation has been conducted, and the Accident and Incident Investigations Division (AIID) has relied on the information submitted by the affected person/s and organisation/s to compile this limited report. The report has been compiled using information supplied in the initial notification, as well as from follow-up desk top enquiries to bring awareness of potential safety issues to the industry in respect of this occurrence, as well as possible safety action/s that the industry might want to consider in preventing a recurrence of a similar occurrence.*

*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.*

***Purpose***

*In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011 and ICAO Annex 13, 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 to apportion blame or liability.*

**Disclaimer**



**This report is issued by:**
**Accident and Incident Investigations Division**
**South African Civil Aviation Authority**
**Republic of South Africa**