1. FACTUAL INFORMATION

1.1. History of the event

While taxiing for a scheduled passenger service from Sydney, NSW, to Lord Howe Island, the crew of the DeHavilland DHC-8 (Dash-8) reported that the aircraft had sustained a deflated left outboard main tyre and was returning to the departure bay. Shortly after, the cabin crewmember advised the flight crew that the tyre appeared to be ‘wet’ and that some passengers had seen smoke coming from the wheel area. The flight crew stopped the aircraft on the taxiway and asked the airport rescue and fire-fighting services (RFFS) to check for signs of fire. After receiving the all-clear, the passengers were disembarked and the aircraft was towed to the operator’s maintenance facility.

1.2. Damage to the aircraft

Maintenance staff found that a section of the bead seat had broken away from the outboard left main wheel rim. That failure had allowed the sudden deflation of the tyre and also fractured a hydraulic line adapter on the brake unit. Because of the shock forces associated with the sudden tyre deflation, the replacement of the opposite (inboard) wheel was also required. No other aircraft damage resulted from the event.

1.3. Aircraft information

Manufacturer	DeHavilland Canada
Model	DHC-8-202
Serial number	439
Registration	VH-TQX
Year of manufacture	1996
Date first registered in Australia	17 March 2000
Allowable take-off weight	16,466 kg
Weight at occurrence	16,000 kg

1.4. Wheel information

The main landing gear wheels installed on the Dash-8 aircraft comprised an assembly of two mating halves, tie bolted together around the circumference.

Manufacturer	BF Goodrich Aerospace
Tyre Brand and size (fitted)	Goodyear Flight Leader, H31 x 9.75-13
Tyre part number (fitted)	319K28-1
Wheel part number	3-1435-3 (assembly)
Wheel serial number	1193/1687
Failed rim part number	300-620-2 (sub-assembly)
Failed rim serial number	1687
Total hours / cycles in service	24,258 h / 29,435 cycles
Total hours / cycles since last inspection	131 h / 128 cycles
Total tyre changes since new	55 (last change 17-7-2003)

1.5. Wheel failure

The failed wheel and tyre assembly was forwarded to the ATSB's Canberra technical analysis laboratory for detailed examination. Initial inspection showed that approximately one half of the bead seat circumference had fractured away from the inner rim hub (figure 1), allowing the tyre to ride completely off the rim. The rim fracture (figures 2, 3) had followed a radial path through the bead seat radius, with a central fracture area exhibiting fatigue crack progression markings originating from a point location on the bead seat radius surface (figure 4). The progression markings extended circumferentially for 110 mm before transitioning to a uniform, featureless, fracture typical of ductile overload failure in high-strength aluminium alloys.

Fig. 1 Left outboard main wheel assembly – as received.

Fig. 2 Section of the inward-facing rim bead seat that had broken away from the wheel rim.

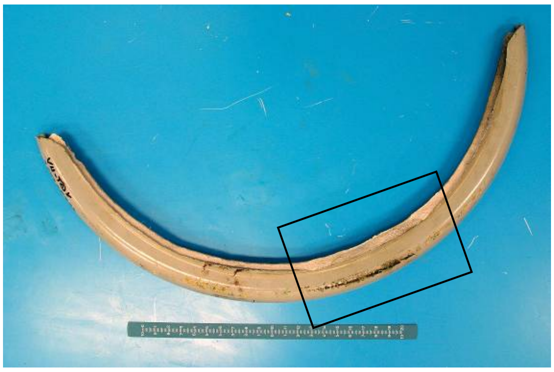

Fig. 3 Inside surfaces of the fractured rim section. The boxed area is shown in greater detail in figure 4

Fig. 4 Fracture surface detail showing crack progression (beach) marks extending from the arrowed location on the bead seat transition radius.

Separation of the rim halves and removal of the tyre allowed inspection of the hub side of the fracture (figure 5 & 6). The fracture features (figure 7) were essentially a mirror of the separated rim section, with fatigue crack progression clearly evident. The crack origin was located approximately 42 degrees around the transition radius between the bead seat and the rim cylinder (figure 8). Optical and scanning electron microscopy of the origin area showed no evidence of pre-existing material or manufacturing defects. A few areas of surface oxide material were shown by metallographic examination to be accumulations of surface contaminants or corrosion products.

Evidence of a localised physical impact on the inboard rim edge (figure 9) was found approximately 35 mm (circumferentially) from the crack origin, although the investigation was not able to establish whether the impact had occurred prior to, or as a result of, the bead seat separation.

Fig. 5 Inner rim half after removal of the tyre.

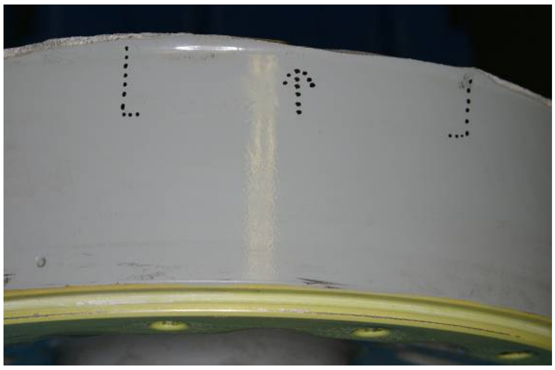

Fig. 6 Cylindrical surface of the inner rim half, with the fatigue crack origin and extent of propagation marked.

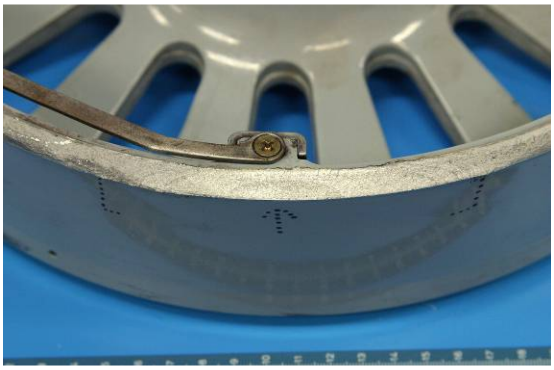

Fig. 7 Fracture features on the rim hub section. Markings as shown in figure 6.

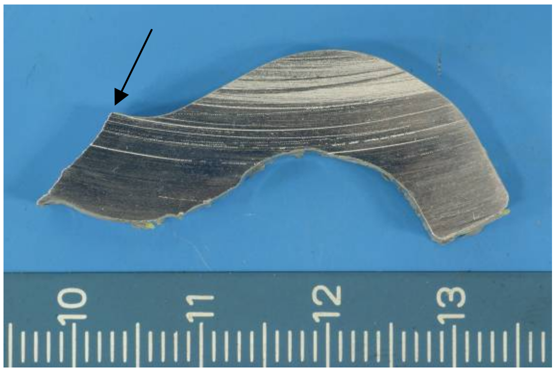

Fig. 8 Cross-section through the bead-seat section showing the crack origin position on the transition radius (arrowed).

Fig. 9 A section of the fractured rim bead seat showing evidence of impact damage on the outer corner (arrowed).

The rim manufacturer indicated that the wheel was produced from a 2014 aluminium forging alloy, solution treated and artificially aged to the T6 condition. Hardness measurements of the wheel alloy adjacent to the location of fracture returned values (85-86 HRB[1]) that compared favourably to published typical values for the 2014-T6 alloy (80-86 HRB[2]).

---

[1] Converted from measured Vickers values in accordance with ATSM E140 'Standard Hardness Conversion Tables for Metals'

[2] Page 68, ASM Handbook, Volume 2, 'Properties and Selection: Nonferrous Alloys and Special-purpose Materials'

1.6. Inspection

The wheel manufacturer published requirements for the periodic non-destructive examination of the wheel assembly[3]. At the time of the last inspection, those requirements specified that the wheel halves must undergo a penetrant or eddy-current inspection of the bead-seat area at every tyre change after the 16th change. Additionally, a mandatory penetrant inspection of the full wheel halves was required at the 25th change and every 10 changes subsequently. In line with necessary practice, the maintenance manual required that all paint be removed from the wheel halves before penetrant inspection. Paint removal was not required for eddy-current inspection.

Inspection documentation received from the aircraft operator indicated that the last inspection of the failed wheel rim half was a full penetrant inspection, carried out during the 55th tyre change, on or about 7 July 2003. The previous (54th tyre change) inspection was an eddy-current examination of the bead seat area and was conducted around 27 March 2003. Both inspection records were endorsed 'Nil Defects Evident'.

When the failure occurred, the aircraft had operated for 128 flight cycles after the last (55th) tyre change.

1.7. Re-design

In December 1994, the wheel manufacturer published service letter BFG SL 1647, detailing the introduction of a new main wheel assembly, part number 3-1435-4, containing a new inner wheel half assembly, part number 300-620-3. The service letter also advised that the part number 3-1435-2 wheel assembly and its respective inner (300-620-2) and outer (300-619-1) half assemblies would not be available following the introduction of the new components.

The service letter stated that the new design wheels were being introduced to improve the fatigue life of the wheel halves, through the incorporation of a compound bead seat transition radius in lieu of the single radius present on the earlier designs. The compound radius provided for a reduction in stress concentration around the bead seat transition region.

[3] Component maintenance manual, Main Wheel Assembly, P/N 3-1435

2. ANALYSIS

2.1. Wheel failure

The left outboard main landing gear wheel rim from Dash-8 aircraft, VH-TQX, failed during taxi as a result of the fracture of a partial section of the inner rim bead seat, fracturing a brake line and deflating the tyre.

ATSB laboratory analysis characterised the rim failure as the result of a progressive fatigue cracking mechanism, initiated from a location on the internal bead seat transition radius. Around the rim circumference, the internal bead seat radius was the region of maximum tensile bending stresses induced by pneumatic pressures and tyre flexure. The dynamic nature of wheel operation results in the generation of cyclic stresses within the rim as the wheel rotates. The orientation of the rim fracture sustained by VH-TQX was consistent with the rim bending forces dominating the initiation and growth of fatigue cracking within the rim section. The investigation did not identify any material or manufacturing defects at the fatigue crack origin that might have contributed to the development of cracking from that area.

2.2. Crack detection

The comparatively short service interval between the rim failure and its last full non-destructive inspection suggests one of two possible scenarios.

1. Initiation and rapid growth of fatigue cracking to critical size in the 128 flight cycles *after* the last non-destructive inspection.
2. Initiation of cracking *before* the last non-destructive inspection and the subsequent failure of that inspection to detect the cracking.

As crack growth rate information for the observed failure mechanism was not available, it was not possible to ascertain the likelihood of either scenario. It should be noted however, that the fluorescent penetrant inspection method prescribed by the component maintenance manual was considered suitable for the detection of bead seat cracking of the nature sustained by the wheel from VH-TQX. In consideration of the likelihood of a failure to detect an existing crack, it is a characteristic of all non-destructive inspection techniques that they have a probability of defect detection (PODD) that is related to the physical size, number, orientation and location of the defects and the parameters of the inspection technique. It thus remains a possibility that a single, small developing fatigue crack may have escaped detection during the last fluorescent penetrant inspection.

3. CONCLUSIONS

3.1. Significant factors

From the investigation of the reported incident, the following factors were identified as being significant to the development of the occurrence.

1. As a result of design deficiencies and accumulated service life, the inner wheel half of the left main landing gear wheel developed a fatigue crack from within the tyre bead seat radius.
2. The concealed location of cracking on the inside tyre bead seat radius prevented it from being detected during routine visual inspections.
3. The cracking had not initiated or grown to a detectable size at the time of the last non-destructive (dye-penetrant) inspection of the wheel, which was carried out at the most recent tyre-change, 128 flight cycles before the failure.
4. Final overload fracture of the wheel rim, after growth of the fatigue cracking to critical size, was sufficient to allow the tyre to release from the bead seat and deflate rapidly.

4. SAFETY ACTION

4.1. Safety action

In 1994, the wheel manufacturer introduced a new main landing gear wheel assembly, incorporating an improved bead seat radius profile that improved the distribution of rim outward bending stresses; enhancing the fatigue resistance of the components. While the original rim assembly was no longer supplied, there was no requirement to replace the existing wheel assemblies with the new items. Following the subject occurrence, the manufacturer introduced steps to accelerate the replacement of the original rim units by amending the component maintenance manual to disallow the intermixing of the original and new configurations and to prevent the acceptance or repair of any damage to the wheel bead seat area.

In December 2003, the wheel manufacturer revised the maintenance manual tyre change inspection schedule that applied to the earlier (P/N 4-1435-3) wheel assembly. The revision incorporated a mandatory penetrant inspection of the full wheel halves at the 50th and *every* subsequent tyre change thereafter. This was in addition to the existing requirement for penetrant inspection at the 25th tyre change and every 10th change thereafter. The additional inspection requirements recognised the increased risk of fatigue crack development in wheels that had high service lives and provided for a more thorough inspection regime to enhance the likelihood of detecting a wheel crack before it grew sufficiently to cause ultimate wheel failure.

To improve the accuracy and probability of crack detection, the manufacturer has provided the operator with eddy current equipment calibration standards for the different wheel configurations and has worked with the operator to procure a suitable bead seat inspection probe. The wheel manufacturer also indicated its intention to recommend the use of eddy current inspection of the bead seat at each tyre change.