



Australian Government
Australian Transport Safety Bureau

Landing gear failure and runway excursion involving Cessna 441 VH-XBC

Coonawarra Airport, South Australia | 31 March 2013



Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation
AO-2013-072
Final – 8 September 2014

Source: Cover photo airport operator.

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Publishing information

Published by: Australian Transport Safety Bureau
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Addendum

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Safety summary

What happened

On 31 March 2013, a Cessna Aircraft Company 441 aircraft, registered VH-XBC, arrived at Coonawarra Airport, SA, following a charter flight from Adelaide, SA. The pilot reported that the initial flare and touchdown was normal, however during the landing roll, he heard a distinct 'pop' or 'bang' sound, after which the aircraft began veering to the left. Initially the pilot was able to maintain directional control and keep the aircraft on the runway, however as it slowed, it began pivoting around the left landing gear and came to rest to the left of the paved runway surface. There were no injuries to passengers or crew.

Failed main landing gear trunnion



Source: ATSB

What the ATSB found

The runway excursion resulted directly from the failure of the left main landing gear trunnion, which allowed the left main wheel to displace upward and contact the wing underside – producing an asymmetric and uncontrolled braking effect. Both the ATSB and component manufacturers' laboratory examinations attributed the trunnion failure to the development and growth of progressive fatigue cracking through the horizontal beam and central gusset section, with cracking propagating to the point where nominal landing loads produced the final overstress fracture and collapse of the assembly. Due to the extent of post-failure damage sustained by the fracture surfaces, neither laboratory examination was able to specifically identify the factors behind the initial development of the fatigue cracking.

The ATSB's research of Australian and international air safety records did not identify any other instances of this specific mode of failure within the trunnion type, nor was the manufacturer aware of any known cracking or related problems with the trunnion in the affected areas. As such, it is likely that the event was an isolated occurrence, and consequently, the likelihood of similar occurrences in the future is low.

What's been done as a result

In response to this occurrence, the aircraft operator undertook a targeted, one-off non-destructive inspection of the trunnions from the four other aircraft in its fleet. All were found to be defect free. Additionally, the operator's maintenance schedule has been extended to include the eddy-current inspection of the trunnion gusset/web regions concurrently with the routine 2000-cycle periodic inspections specified by the aircraft manufacturer.

Safety message

While the failure sustained in this instance was an unusual and isolated case, it does highlight the necessity of general vigilance and attention to detail during general visual inspections, or during other examinations of structures and components. Such activity can present opportunities for the detection of emerging or unknown airworthiness issues that may not have otherwise been identified during prescribed maintenance programs.

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The occurrence

On 31 March 2013, a Cessna 441 aircraft, registered VH-XBC, was conducting a scheduled charter flight from Adelaide, South Australia (SA) to Coonawarra, SA with the pilot and nine passengers on board. Following what was reported as a normal approach and touch down, the pilot stated that upon selecting reverse thrust, he heard a 'pop' or 'bang' sound accompanied by a shudder through the airframe. The aircraft then began to veer to the left, and while the pilot was initially able to maintain directional control, the aircraft began to pivot around the left landing gear as it slowed, finally coming to rest just off the left side of the paved surface, at an angle of about 45 degrees to the runway heading (Figure 1). The pilot and passengers were uninjured during the event and all were able to exit aircraft safely after the engines were shut down.

Figure 1: VH-XBC following the landing event at Coonawarra, SA



Source: Aircraft operator

Visual inspection of the aircraft in preparation for its removal from the runway area found that the left main landing gear had partially collapsed after the fracture of the main trunnion section (Figures 2 and 3). The trunnion failure had allowed the uncontrolled upward movement of the strut and swing arm, bringing the left main wheel into contact with the wing and producing a strong asymmetric braking effect that resulted in the aircraft veering to the left and departing the runway surface. The aircraft operator reported only minor damage to other components and parts.

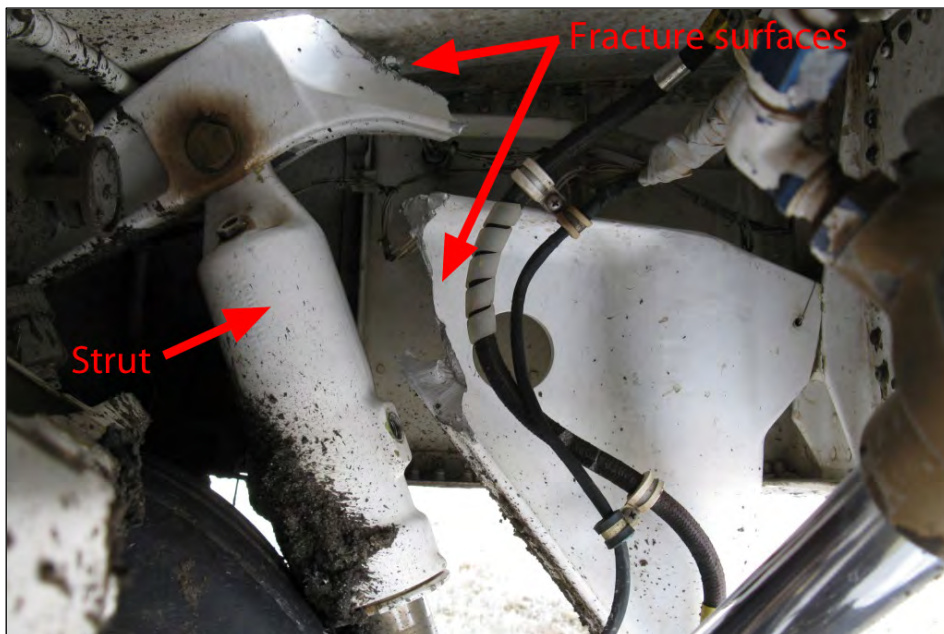
Following recovery of the aircraft, the fractured trunnion was removed and submitted for technical examination as part of the ATSB's investigation into the occurrence.

Figure 2: Left main landing gear position following landing



Source: Aircraft operator

Figure 3: Magnified view of damaged main landing gear



Source: Aircraft operator

Context

Aircraft information

The Cessna 441 Conquest II (serial number 441-0297) was a pressurised, all metal, low wing, twin turboprop aircraft. It was powered by two Garrett TPE331 turboprop engines - each driving a four-blade, constant-speed, fully feathering and reversible propeller.

The aircraft (VH-XBC) was manufactured in the United States in 1983 and had accrued a total time in service of 8,629.8 hours (TSN) and 10,895 flight cycles (CSN).

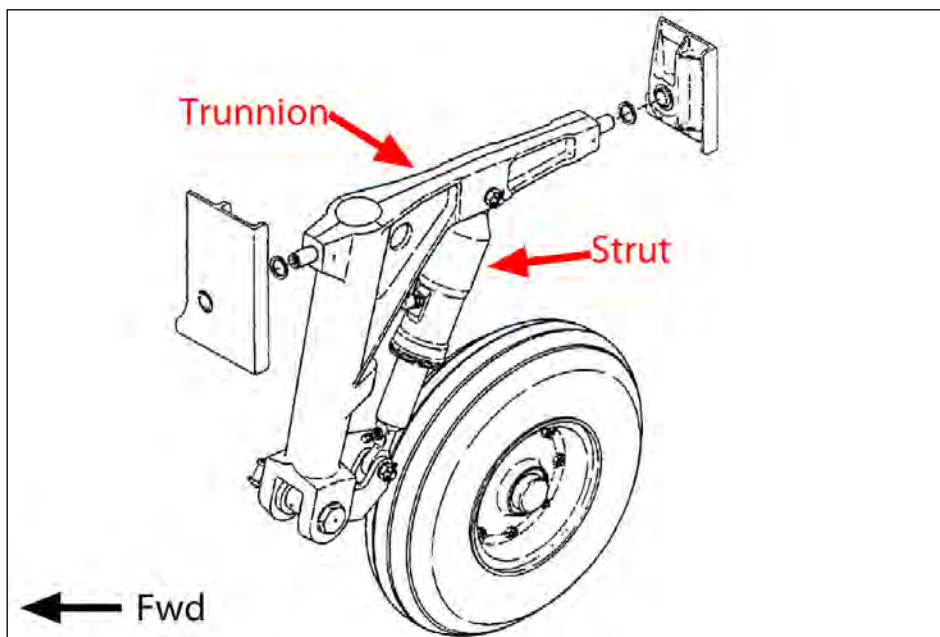
Landing gear

The Cessna 441 retractable tricycle landing gear was hydraulically actuated and comprised two inward-retracting main gear, each carrying a single wheel and brake assembly supported on a trailing axle, and a rearward-retracting nose gear carrying a single wheel.

The main gear assembly consisted of a trunnion (part number 5741115), shock strut and fork/axle assembly (Figure 4). The gear was mounted within the inner wing structure and pivoted longitudinally between front and rear trunnion pins. The shock strut supported the landing gear static and dynamic loads and acted to dampen transient loads during landing, take-off and taxiing.

The trunnion unit was a common component across the Cessna 404, 406, F406 and 441 aircraft types.

Figure 4: Cessna 441 main landing gear configuration



Source: Aircraft maintenance manual

Trunnion unit

The general engineering specifications for the trunnion stated that it was manufactured as a forging from a UNS 97175 (AA7175) aluminium alloy; heat-treated to the T74 temper condition and machined to either the left or right side configuration.

The aircraft manufacturer advised that the main landing gear trunnion units had been produced by a specialist third-party vendor to prescribed requirements and specifications. While specific production records for the trunnion fitted to VH-XBC were not available¹, general information noted that all new components were subjected to a regime of mechanical and non-destructive quality control testing after receipt. Physical load/strength testing was also specified for one sample per lot of components produced.

Trunnion examination

Metallurgical examination of the failed trunnion was carried out in the ATSB's Technical Analysis facility – focussing on establishing the characteristics of the component fractures and the condition of the base material. Appendix A to this report presents a summary of the examination performed. At the ATSB's request, a subsequent examination and analysis of the failure was also conducted by the aircraft/component manufacturer, in an endeavour to better comprehend the complex fracture characteristics.

Both examinations confirmed the trunnion as having been manufactured (as-specified) from an AA7175 aluminium alloy, with hardness and conductivity levels consistent with the required T74 temper condition. The principal fracture surfaces suggested the initial development of failure as a progressive fatigue cracking mechanism, however the origins of fracture initiation were uncertain. General fracture form, morphologies and stress distribution suggested cracking commenced from the trunnion horizontal beam upper flange, however post-failure damage to that area precluded any further interpretation of value. The analysis was made more complex by the existence of an area of internal centreline separation observed within the forged gusset webbing. Fatigue cracking intersected this region at both extremities, however the separation surfaces themselves presented little detail of value. Operational loads from the landing at Coonawarra, in the presence of the pre-existing cracking, produced the final overstress fracture and the landing gear collapse.

Maintenance

Maintenance records for the aircraft showed that in May/June 2009, at 7,370.5 hours TSN / 9,407 CSN, both main landing gear trunnions from VH-XBC had been removed for inspection in accordance with maintenance manual supplemental inspection number 32-10-05. The inspections included a visual examination of the upper and lower regions of the trunnion for cracks, overload deformation and corrosion as well as eddy current inspection of specific regions. The supplement required an initial inspection at 10,000 flight cycles or 15 calendar years, followed by repeat inspections every 2,000 flight cycles or 4 calendar years. The supplementary inspections did not specify or require any targeted non-destructive inspection at, or around, the area of failure sustained by the trunnion from VH-XBC.

The aircraft maintenance records contained no entries relating to non-routine maintenance or repairs to the landing gear stemming from heavy/hard landings or other related events.

Previous occurrences

The aircraft manufacturer advised that there had been no known failures of the part number 5741115 or similar landing gear trunnions in this location. Similarly, a review of the ATSB's occurrence database, the Australian Civil Aviation Safety Authority's *Service Difficulty Report* (SDR) database and the US Federal Aviation Administration's SDR database provided no indication that previous failures of this type had been encountered.

¹ Production records for the trunnions were only retained by the manufacturer for 10 years.

Safety analysis

Occurrence event

The runway excursion that occurred on 31 March 2013 involving a Cessna Aircraft Company 441 registered VH-XBC was a result of the failure and partial collapse of the aircraft's left main landing gear. A single fracture through the horizontal element of the landing gear trunnion allowed the strut and fork/axle assembly to move upward, bringing the left main wheel into contact with the wing underside. The subsequent asymmetric braking effects and wheel tracking changes created the directional control difficulties experienced by the pilot and ultimately led to the aircraft departing the left side of the runway at low speed.

Trunnion failure

Failure of the landing gear trunnion occurred primarily from the effects of a progressive fatigue cracking mechanism that had extended through the central web section of the reinforcing gusset between the trunnion's horizontal beam and the cylindrical leg. Cracking had propagated through the horizontal beam and web; driven by bending stresses associated with the transient loads carried by the landing gear assembly. Final rupture of the trunnion occurred through rapid overstress fracture of the remaining lower flange section.

The ATSB's metallurgical examination of the trunnion fracture identified an unusual region of planar separation aligned with the mid-thickness of the web section. The surface morphology of the region was unlike the adjacent areas of fatigue or overstress fracture, in that it was predominantly flat and featureless; presenting the appearance of coarse crystallographic facets aligned along a single plane. Having regard to the production of the trunnion as a forging, the material microstructure in this region is highly directional – having an aligned grain structure that was analogous to a length of layered wood. The separation had occurred along this structure; promoted by the expected highly anisotropic² mechanical properties which would promote fracture along the grain, rather than across it.

Based on the fractographic and metallographic evidence, it was clear that the trunnion failure exhibited areas of both progressive fatigue cracking and rapid overstress rupture at the limits of the fatigue crack growth. Due to the combination of influences of the highly directional material microstructure and the physical damage sustained after the landing gear collapse, it was not possible to identify the origins of fatigue cracking with the necessary levels of confidence. Nevertheless, both the ATSB and manufacturers' examinations found no other anomalous features or characteristics within the trunnion material or structure that could be held as contributory to the failure sustained. The material of manufacture was as-specified, and the microstructure and general hardness levels suggested the heat treatment had been conducted satisfactorily.

Inspection

Post-manufacture

While the aircraft manufacturer indicated that the newly-manufactured trunnion components had been subject to a complete-coverage non-destructive inspection, the manufacturer's 10-year limited document retention policy meant that the specific inspection records for the trunnion in question were no longer available. As such, the investigation was unable to confirm the veracity of that inspection, or the presence or otherwise of any localised flaw that may have been the subject of an engineering assessment and concessional acceptance process.

² Having properties that differ according to the axes of measurement i.e. across the grain versus along the grain.

Maintenance

During operational service, aircraft landing gear are routinely subject to significant transient and repetitive loads, and as such, periodic inspection and routine maintenance plays an important role in ensuring the ongoing reliability and safety of the assembly.

The principal in-service inspections for the part number 5741115 trunnion were defined in maintenance manual supplement 32-10-05 and had been conducted in January 2009; at 1,259.3 hours / 1,488 cycles prior to the failure in March 2013. While the inspection included targeted eddy-current examination of the major trunnion fixtures and load-bearing elements, there was no inspection defined for the central gusset area through which the failure subsequently occurred.

In light of the absence of any historical reports of previous trunnion failures or defects in the gusset area, it was likely that the manufacturer saw no merit in requiring repeated inspections of this region.

Findings

From the evidence available, the following findings are made with respect to the runway excursion and landing gear failure of a Cessna Aircraft Company 441, registered VH-XBC, that occurred at Coonawarra Airport, SA on 31 March 2013. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Safety issues, or system problems, are highlighted in bold to emphasise their importance.

A safety issue is an event or condition that increases safety risk, and (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

Contributing factors

- Dynamic stresses on the trunnion associated with landing gear operation produced the initiation and growth of fatigue cracking within the trunnion horizontal beam and central web sections.
- The manufacturer's instructions for the periodic in-service inspections of landing gear trunnions that have exceeded 10,000 flight cycles or 15 years of age, did not include requirements for the targeted examination of the central gusset and web region, from which the cracking and failure originated.
- Previous in-service inspections of the landing gear trunnion had not identified the developing fatigue cracking.
- After the growth of fatigue cracking to critical size, the final overstress fracture of the remaining trunnion section occurred during the landing at Coonawarra on 31 March 2013.

Other findings

- The ATSB investigation did not identify any other historical instances of manufacturing defects or failures resulting from cracking within the gusset/web area of the part number 5741115 (or similar) landing gear trunnions.

Safety issues and actions

Safety action

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence

Proactive safety action taken by: Aircraft operator

The operator of VH-XBC has advised that after the landing gear failure, all Cessna 441 aircraft in its fleet have undergone a targeted inspection of the trunnion gusset/web areas using visual and eddy-current techniques. No defects were found. In addition, the operator has introduced an eddy-current inspection of the gusset/web area – to be conducted concurrently with the inspections required by maintenance manual supplement 32-10-05.

Action number: AO-2013-072-NSA-013

General details

Occurrence details

Date and time:	31 March 2013 – 1015 ACDT	
Occurrence category:	Serious incident	
Primary occurrence type:	Runway excursion	
Location:	Coonawarra Airport, South Australia	
	Latitude: 37° 16.77' S	Longitude: 140° 48.68' E

Aircraft details

Manufacturer and model:	Cessna Aircraft Company 441	
Registration:	VH-XBC	
Serial number:	4410297	
Type of operation:	Charter	
Persons on board:	Crew – 1	Passengers – 9
Injuries:	Crew – 0	Passengers – 0
Damage:	Substantial	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- Cessna Aircraft Company / Textron Aviation
- Aircraft operator

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to Textron Aviation, the aircraft operator, the Civil Aviation Safety Authority (CASA) and the National Transportation Safety Board.

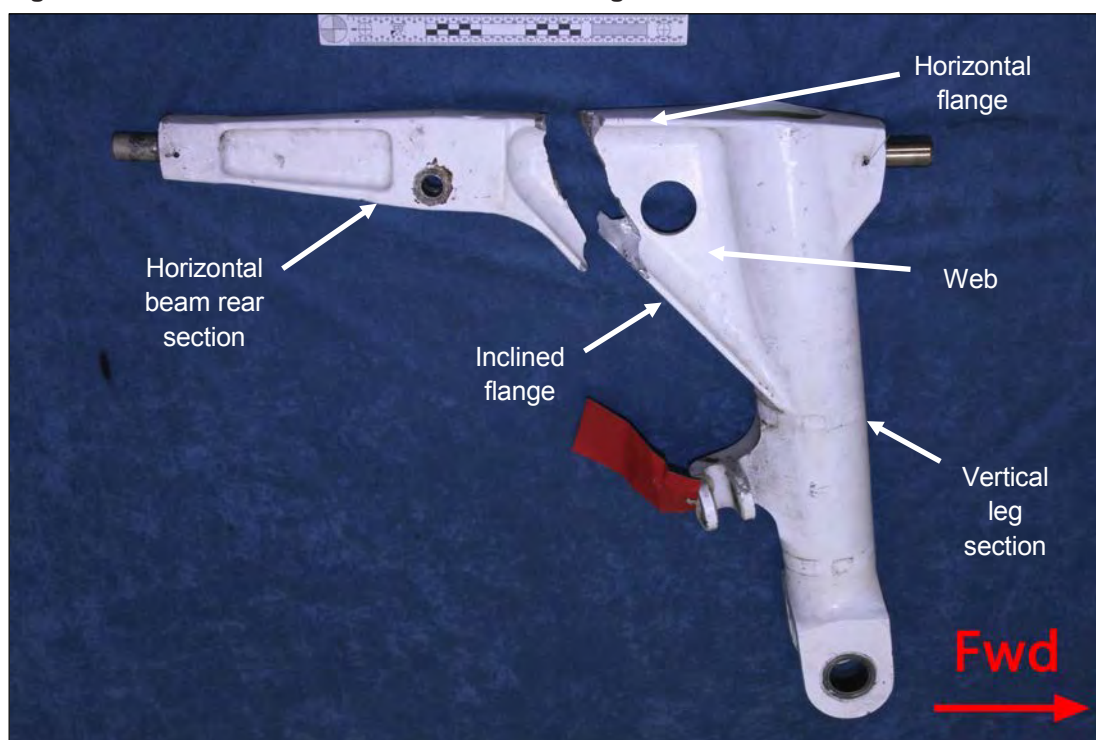
Submissions on the draft report were received from Textron Aviation. After review, the text of the final report was amended where it was considered appropriate to do so.

Appendix A

Technical examination of the trunnion failure

As depicted in Figure A1, the trunnion had fractured through the web between the strut attachment point and the vertical leg – following a plane roughly parallel to the leg axis.

Figure A1: Trunnion removed from XBC showing fracture location



Source: ATSB

Macroscopic study

The fracture surfaces through the horizontal and vertical flange sections presented areas of heavy mechanical deformation and contamination that were consistent with post-failure mechanical contact and damage (Figure A2). Between these areas, the general surface morphology was consistent with overstress fracture in higher strength aluminium alloys.

Within the central webbing section toward the area of transition to the inclined flange (Figure A3), the fracture presented a notable transition to a region of brighter, lustrous surface with patterned characteristics suggestive of a progressive crack growth mechanism. Closer study of this region revealed an unusual area of internal separation aligned along the web centreline (Figure A4). In areas, the internal surfaces of this region showed a quasi-crystallographic appearance of broad facets aligned along a single plane. Targeted mechanical sectioning allowed removal of a section of the web transition and the exposure of a larger area of the internal planar feature (Figure A5). Under stereomicroscopic examination, the intersection of the planar separation and transverse progressive crack pathways could be clearly discerned (Figure A6).

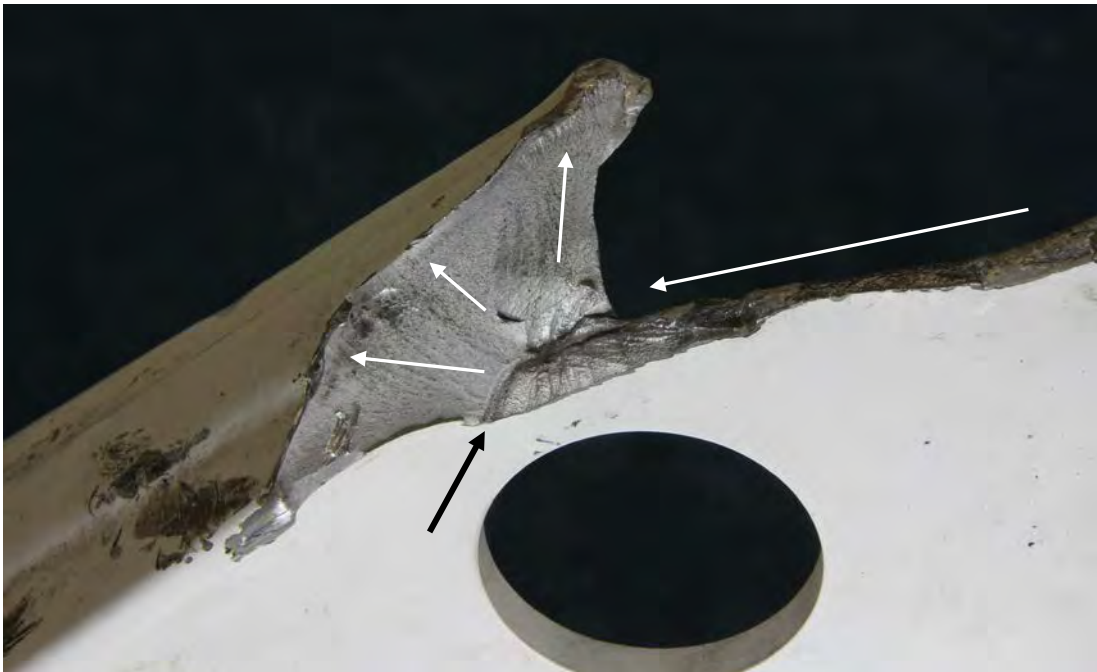
In areas along the progressive cracking, fine secondary cracks were apparent beneath the external paint coating (Figure A7).

Figure A2: Fracture surface from vertical leg section – possible fatigue crack origin at damaged upper flange corner (arrowed)



Source: ATSB

Figure A3: Fatigue / overstress fracture transition adjacent to the inclined flange (black arrow), and fracture pathways / direction (white arrows)



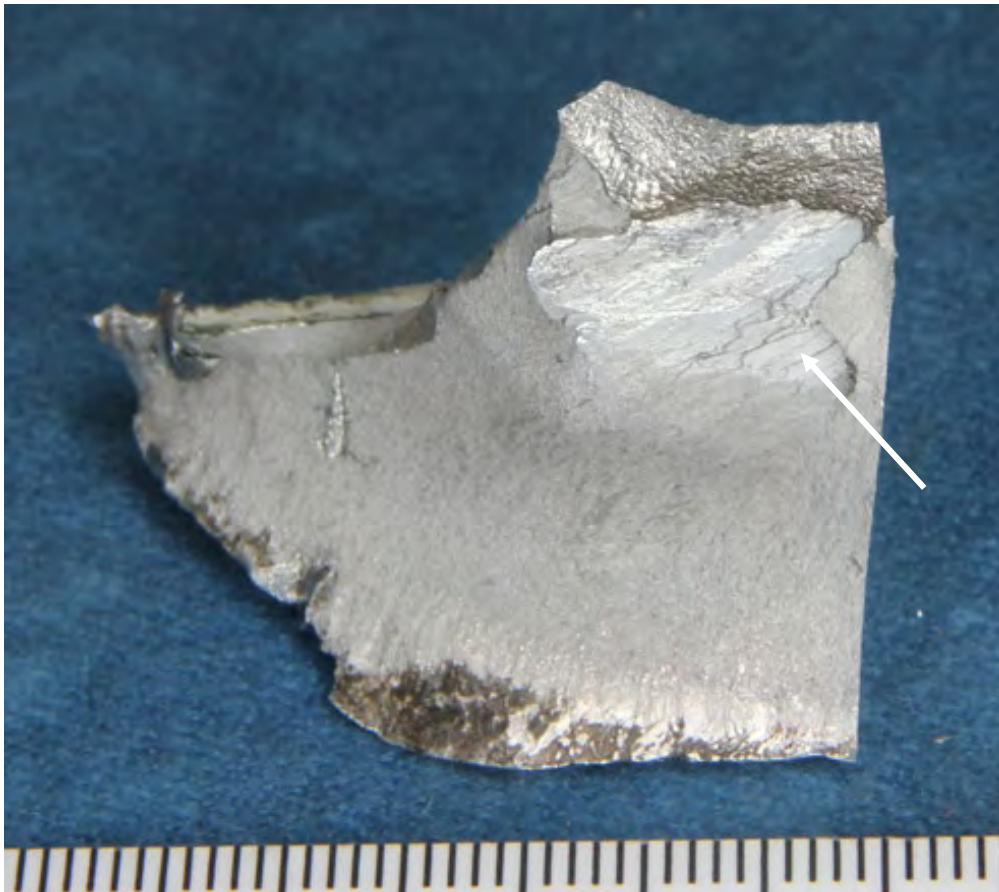
Source: ATSB

Figure A4: Inclined flange transition region of fracture (horizontal beam rear section) showing internal separation of the web (arrowed)



Source: ATSB

Figure A5: Removed section of the trunnion fracture showing part of central planar separation (arrowed)



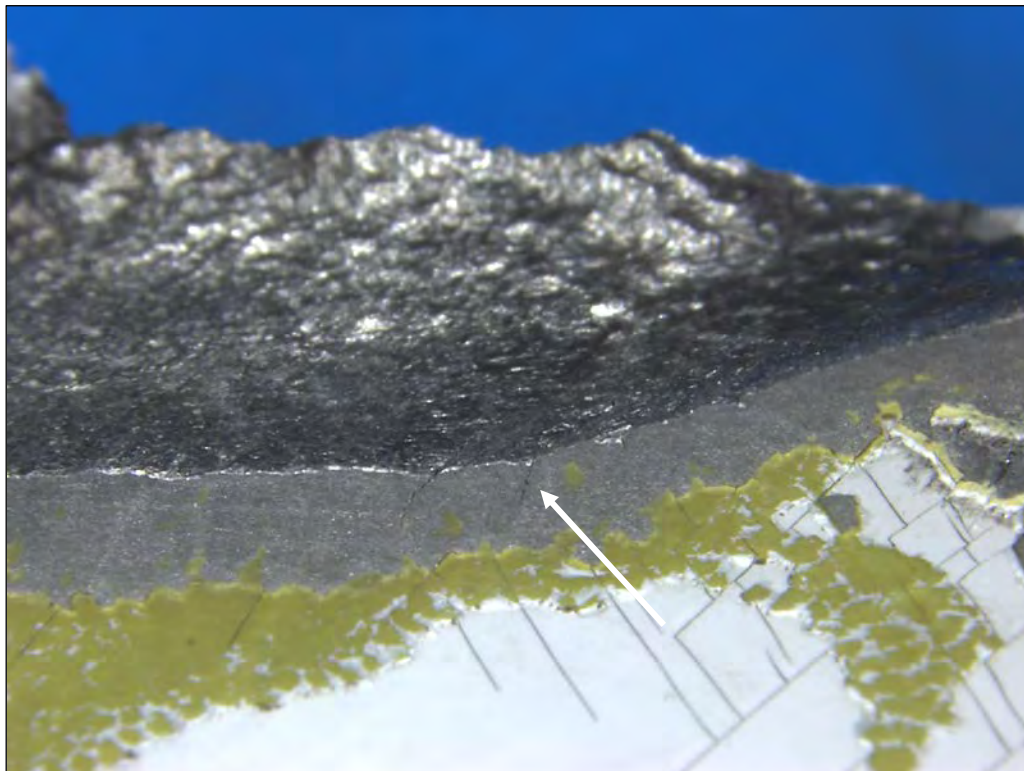
Source: ATSB

Figure A6: Intersection of central planar separation feature (piece shown in figure A5) with transverse progressive cracking (after sectioning). Arrows show direction of fatigue propagation



Source: ATSB

Figure A7: Secondary cracking (arrowed) extending from the primary progressive region.



Source: ATSB

Scanning electron microscopy

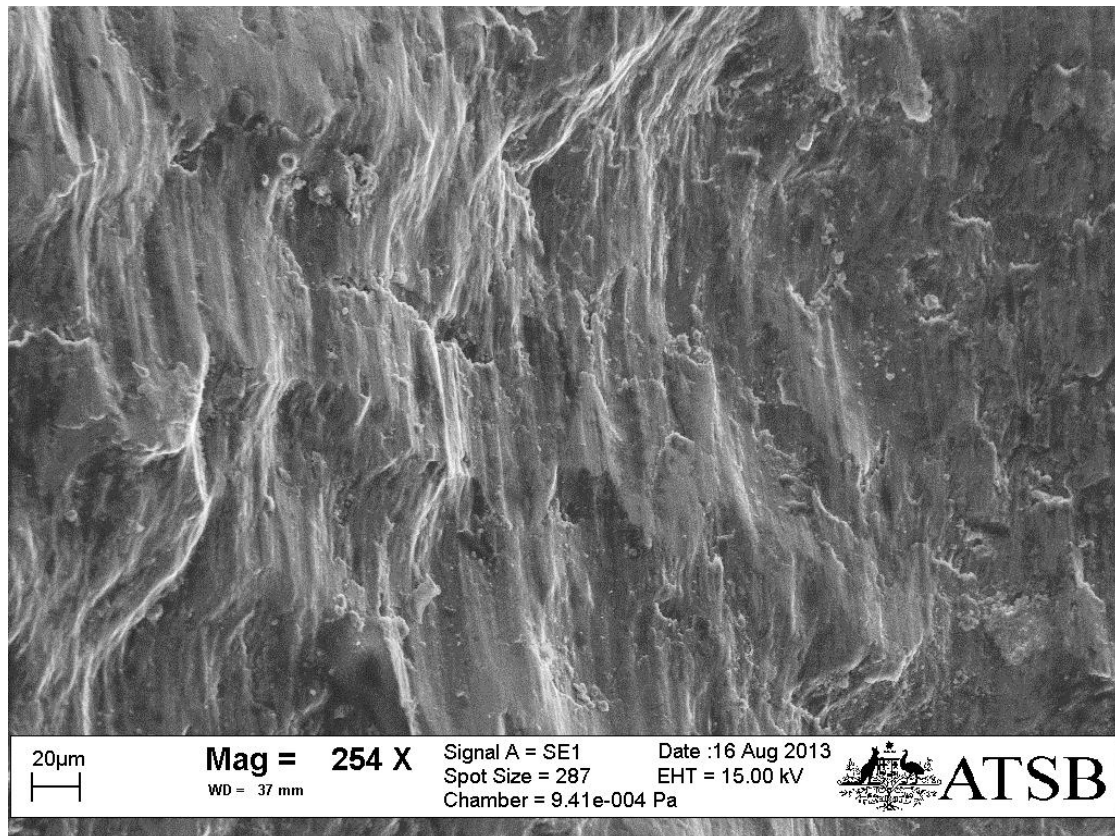
Select areas of the trunnion fracture surfaces were examined in detail under the scanning electron microscope (SEM), including:

- the central region of crystallographic/faceted appearance,
- areas of progressive fracture, and
- areas of overstress fracture.

While the areas of progressive cracking were somewhat burnished and flowed from suspected inter-surface contact, the SEM examination highlighted the presence of regular and repeating surface patterns that were suggestive of a fatigue cracking mechanism (Figure A8). Outside of the fatigue regions, the surfaces transitioned to an irregular, undulating morphology that was consistent with a ductile overstress failure (Figure A9).

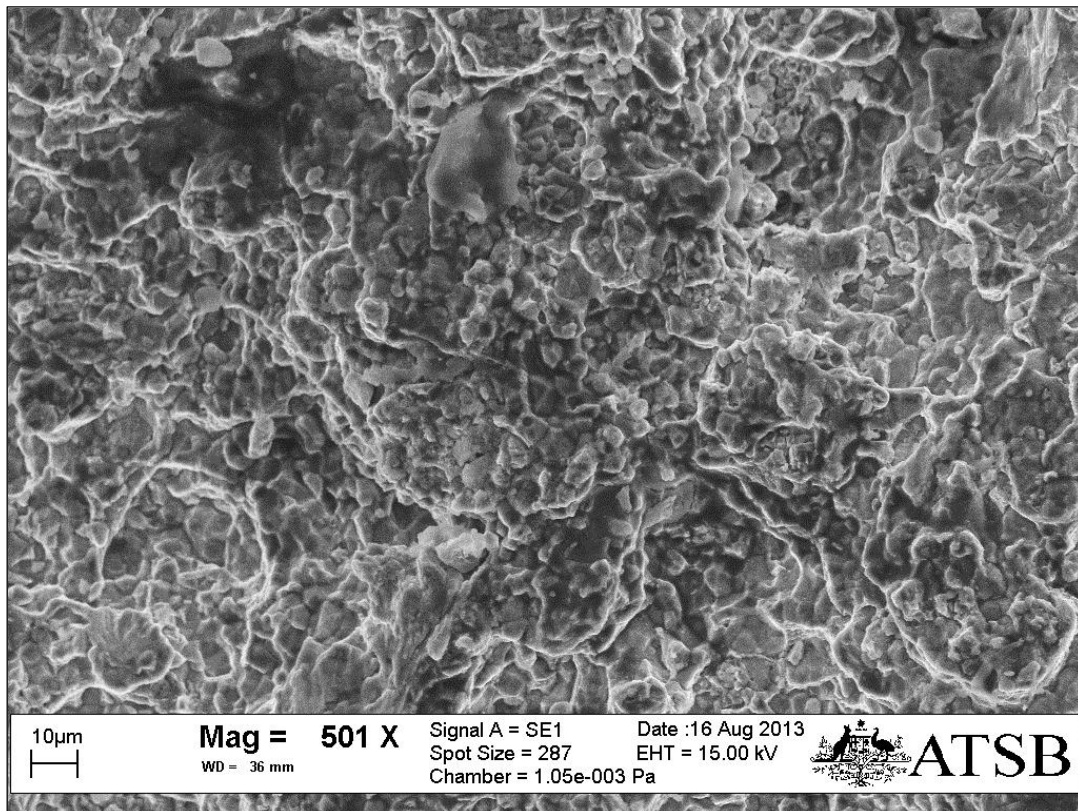
The central area with a distinct crystallographic/faceted appearance was smooth and relatively featureless, with localised regions of mechanical smearing and flow (A10). There were no identifiable fracture characteristics and no suggestion of directionality or progressive crack growth.

Figure A8: Fatigue area – some surface flow and deformation



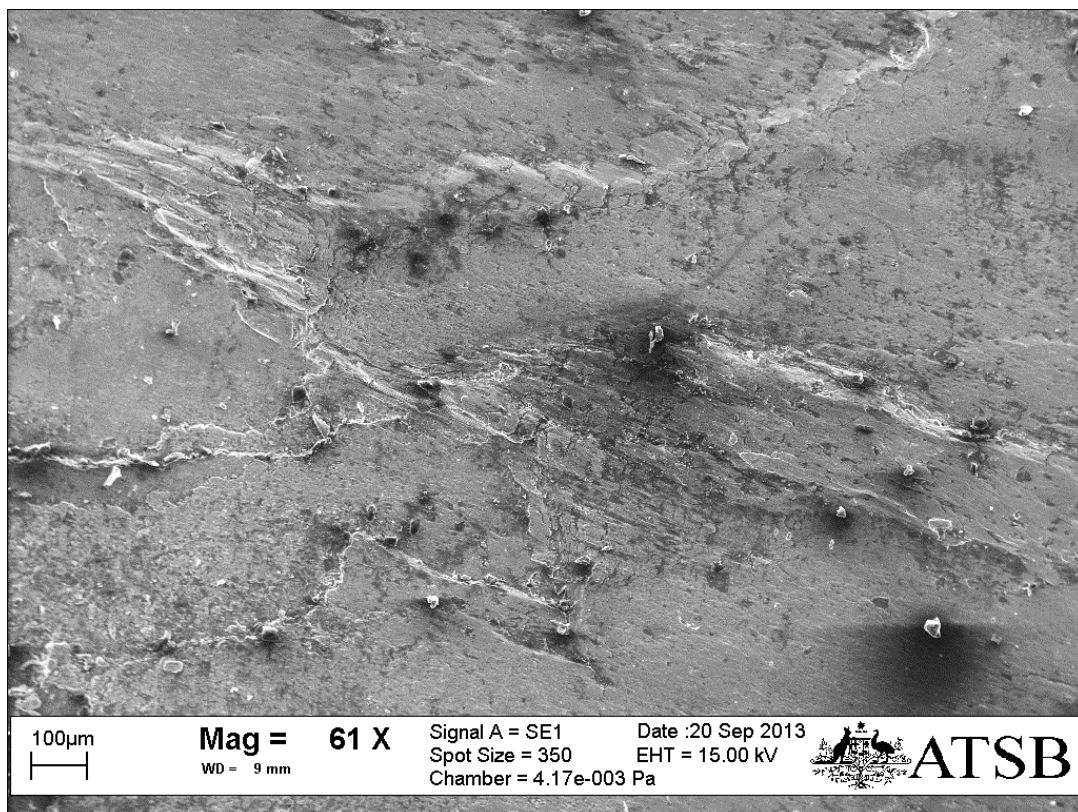
Source: ATSB

Figure A9: Overstress area of fracture surface – dimpled rupture



Source: ATSB

Figure A10: Internal planar area of fracture surface – generally featureless



Source: ATSB

Microstructural examination

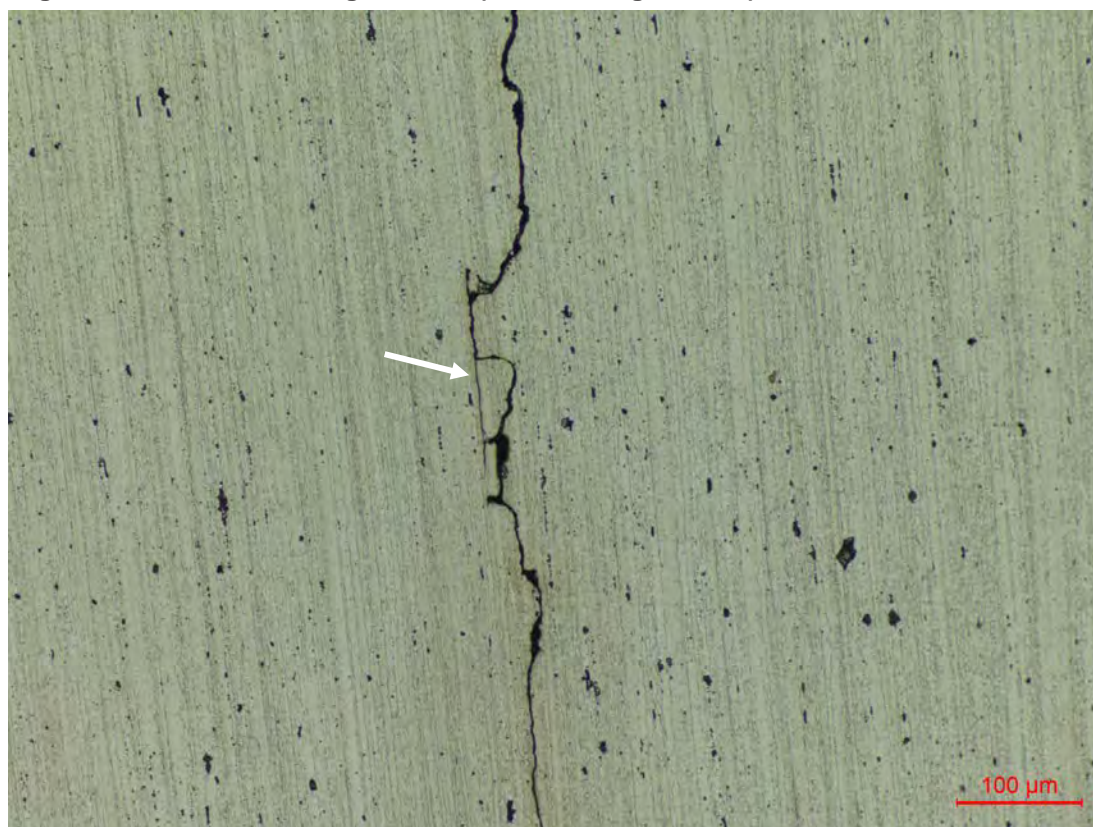
To permit study of the trunnion base material microstructure and the propagation characteristics of the various fracture modes, a selection of transverse sections were mounted and prepared for metallographic examination.

The core material microstructure consisted of heavily deformed α -aluminium grains with a dispersion of fine precipitates and non-metallic inclusions throughout. The microstructure presented a dominant directional grain flow - consistent with production of the trunnion as a forging, and there was no evidence of recrystallization or other atypical structures observed within the sections examined.

Of the sections examined as part of this study, several showed the coincidence of two unique fracture modes. Figure A11 shows a small linear defect aligned tightly with the orientation of the principal grain flow; from this extended several transgranular cracks with a curving propagation path. Other adjacent regions presented a stepped propagation path that was aligned with the directional grain flow (Figure A12).

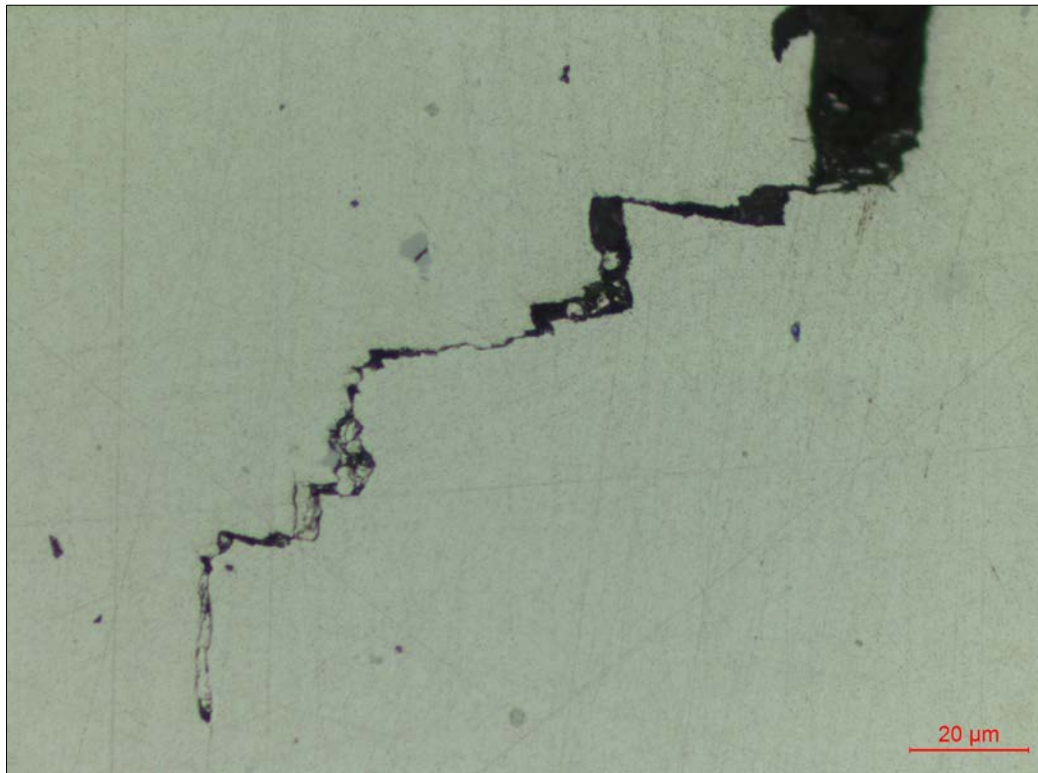
Shallow grain deformation/flow and minor cracks were observed across the surfaces of most of the progressive fracture (Figure A13) – consistent with the effects of repeated inter-surface contact prior to final trunnion fracture.

Figure A11: Transgranular cracking extending from a fine linear separation (arrowed) aligned with the dominant grain flow (Keller's reagent etch)



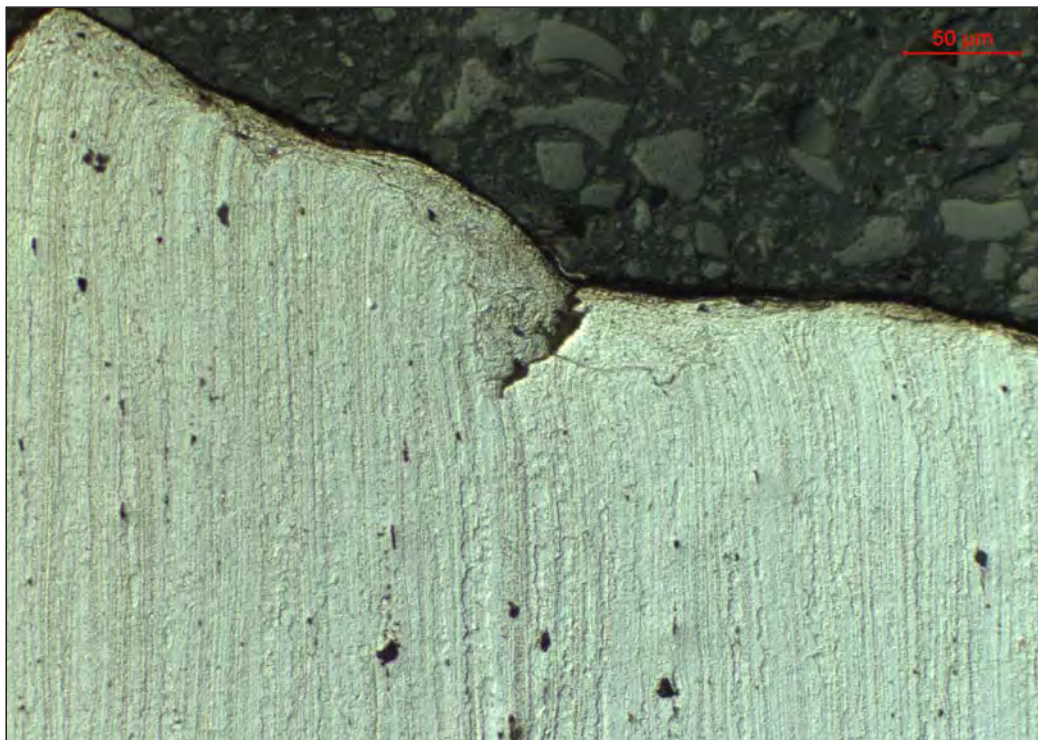
Source: ATSB

Figure A12: Step-wise crack extending from primary fracture surface (unetched).



Source: ATSB

Figure A13: Grain deformation and cracking observed on exposed crack surface



Source: ATSB

Material properties

Spectrographic (chemical) analysis of a sample of the trunnion material returned results consistent with its production from an ISO 97175 (7175) aluminium alloy (as specified).

Table A1: Chemical composition (weight %)

	Al	Si	Cu	Fe	Mg	Zn	Cr	Ni	Mn	Ti	Sr	Zr
Trunnion	Bal	.07	1.76	.11	2.56	5.80	.20	<.01	.02	.01	<.001	<.005
7175	Bal	<.15	1.2- 2.0	<.20	2.1- 2.9	5.1- 6.1	.18- .28	<.05	<.1	<.1	<.05	<.05

Bal – denotes balance of composition

Hardness and electrical conductivity results were also consistent with the specified alloy type in the T74 heat-treated condition.

Table A2: Hardness and conductivity measurements

	Hardness (H _{MV0.3})	Conductivity (%IACS)
Trunnion	170-172	40-42
7175 – T74 (typ)	145 HB (~ 171 HV)	40

Australian Transport Safety Bureau

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

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Investigation

ATSB Transport Safety Report

Aviation Occurrence Investigation

Landing gear failure and runway excursion involving
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