Australian Government
Australian Transport Safety Bureau

Failure of wheel on locomotive SCT 008

near Fisher, South Australia | 28 May 2011

Investigation

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Rail Occurrence Investigation
RO-2011-009
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Addendum

Page	Change	Date

Safety summary

What happened

On Saturday 28 May 2011, intermodal freight train 5MP9 was travelling from Melbourne to Perth when one of its locomotives (SCT class) experienced a catastrophic wheel failure near Fisher, South Australia. The locomotive did not derail but sections of the broken wheel damaged a traction motor and associated components. The train travelled about 1976 m after the wheel failed and caused some sleeper damage and four breaks in the rail.

View of fractured wheel on locomotive SCT 008

Source: SCT Logistics

What the ATSB found

The investigation found that a fatigue crack had initiated at a small indentation on the inside of the wheel rim and then radiated towards the flange and tread regions before the wheel completely failed.

The rate of growth of the fatigue crack was influenced by high in-service mechanical loading of the wheel.

Inspection and measurement after the incident revealed that the locomotive wheel had sufficient rim, tread and flange thickness and was not worn beyond its service life, however it was likely the crack was present at a previous visual inspection and was not detected.

What's been done as a result

The locomotive owner and maintenance provider has advised that they have implemented a revised program for more regular wheel re-profiling of its SCT class locomotive wheels to remove surface stressors in the wheel rim.

The locomotive maintenance program has also been enhanced to include a focus on visual inspections to detect impact damage to wheels and scheduled ultrasonic testing of locomotive wheels after mid-life is carried out when they are machined to detect cracks that may not be visible to the naked eye.

Safety message

Operators of locomotives that are exposed to high in-service mechanical loadings should be aware of the potential for wheel failure due to fatigue cracking and ensure inspection and maintenance programs include techniques for detecting and assessing wheel defects with the potential to lead to fatigue cracks.

Contents

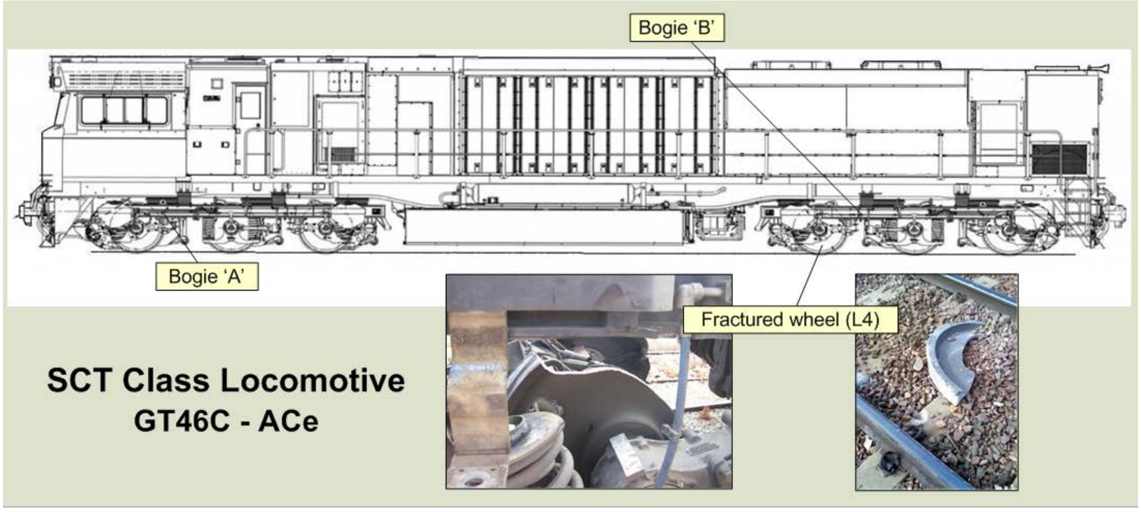
The occurrence

Train 5MP9 was a Perth bound intermodal freight train owned by SCT Logistics (SCT) that originated in Melbourne, Victoria. It travelled through Adelaide where wagons and loading were added to the consist. On Friday 27 May 2011 at 1036[1] the train departed Adelaide. It consisted of two locomotives, SCT 008 (leading) and SCT 006 (trailing) hauling an in-line locomotive refuelling wagon, a crew accommodation coach and 72 freight wagons. The total length of the train was 1787 m weighing a total of 6015 t.

The train travelled through Port Augusta at 1446 and Tarcoola at 2026. At 2144 the train stopped at Wynbring to allow an opposing train (5PM5) to cross. Train 5MP9 departed Wynbring 17 minutes later and at 0104 the next day was diverted into the crossing loop at Watson to enable freight train 5PS6 to cross. After leaving Watson and at about 0145 while travelling at 111 km/h, the crew experienced a violent vibration in the lead locomotive near the 849.700 km mark[2].

The driver made a brake application and 1 minute and 40 seconds later brought the train to a stop near the 851.500 km mark. An inspection of the lead locomotive by the train crew revealed that the left wheel on the leading axle in the trailing bogie (L4[3]) had failed catastrophically (Figure 1). The train had travelled about 1976 m after the failure of the wheel.

Figure 1: Diagram showing position and fractured components on SCT Class locomotive



Source: SCT Logistics

Post occurrence

Following an inspection of the train the driver contacted the Australian Rail Track Corporation (ARTC) network controller to advise that lead locomotive SCT 008 had experienced a catastrophic wheel failure and that about half the wheel had disintegrated (Figure 2). The crew also advised that they would inspect the track for damage and communicate their findings to network control. The track inspection established that the southern rail had incurred impact marks from the damaged wheel to the running surface of the rail and four breaks with gaps of 25 mm - 65 mm were identified. The rest of the train behind the lead locomotive passed over the broken rail sections without derailing.

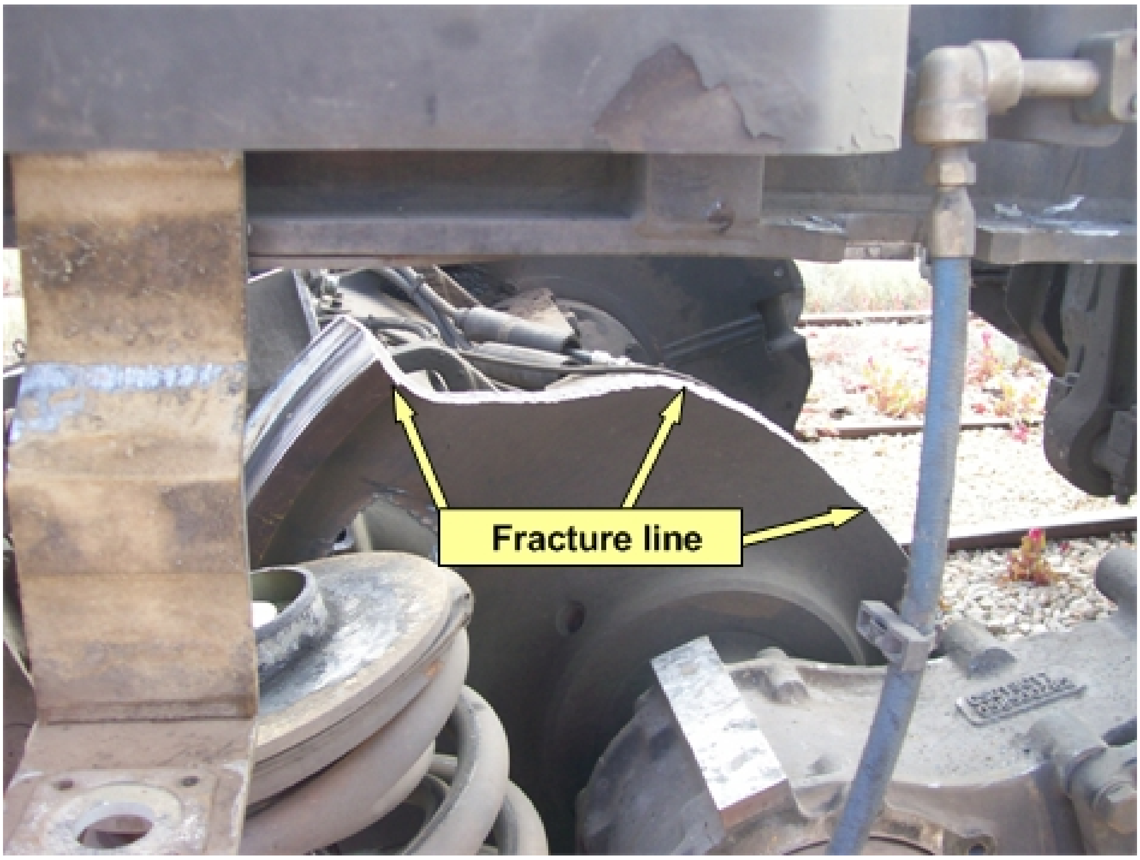
1 The 24-hour clock is used in this report. Australian Central Standard Time (CST), UTC + 9.5 hours.

2 Distance in rail track kilometres from a track reference point located at Coonamia, South Australia.

3 Abbreviations within this report refer to relative positions of wheels on a locomotive. e.g. L4 refers to the fourth wheel from the front of the locomotive on the left hand side; R5 refers to the fifth wheel on the right hand side etc.

Locomotive maintenance workers were despatched from Port Augusta to carry out temporary repairs. They arrived on site about 10 hours after the incident. After being uncoupled from the train, locomotive SCT 006 was used to push locomotive SCT 008 at low speed into the crossing loop at Fisher. Locomotive SCT 006 was later re-coupled to the remaining portion of the train near the incident site and departed at 1924 on Sunday 29 May 2011.

Figure 2: SCT 008 fractured locomotive wheel L4 in situ



Source: SCT Logistics

Track maintenance workers carried out repairs to damaged rail and sleepers with the track returned to normal service on Sunday 29 May 2011 after a delay of about 42 hours.

Locomotive SCT 008 was temporarily repaired while stabled on the crossing loop at Fisher and the damaged traction motor wheel/axle assembly was removed and replaced with a working axle/wheel set. On Thursday 2 June 2011 the locomotive was attached to SCT train 4PM9 whereupon it travelled to Port Augusta for further repairs.

Context

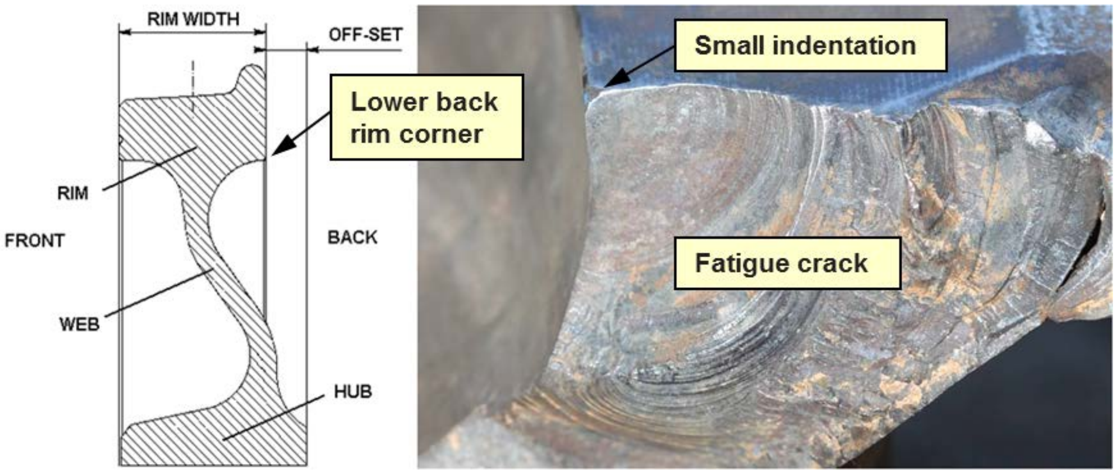
Locomotive SCT 008

Locomotive SCT 008 was one of 15 SCT class (GT46C–ACe) locomotives built by Downer EDI Rail (DEDI) in Cardiff, New South Wales that entered service in May 2008. The SCT class is a diesel electric locomotive producing 3207 kW (4300 HP). It is equipped with two three-axle bogies, and is driven by six AC[4] traction motors. The SCT class locomotive fleet is serviced and maintained by DEDI.

Fractured wheel L4

The wheel/axle assembly and broken segments were transported to Melbourne, Victoria where a detailed examination was carried out by DEDI and the Monash University – Institute of Railway Technology (IRT). IRT was commissioned by SCT and DEDI to examine the failed and mating wheels for compliance with relevant material and manufacturing standards, to examine the crack growth behaviour and to identify the root cause(s) of the wheel failure. The Australian Transport Safety Bureau (ATSB) witnessed the metallurgical examination of the fractured wheel and actively monitored the investigation work undertaken by IRT, DEDI and SCT.

Figure 3: Wheel terminology and small indentation



Source: RISSB - Standards Australia

It was concluded that the failure of wheel L4 resulted from a fatigue crack that initiated on the lower back rim face corner at a small indentation measuring about 1 mm in depth[5] (Figure 3). The crack had propagated towards the wheel flange and tread regions before the wheel catastrophically failed in overstress. The failure of wheel L4 was considered to have occurred primarily under the influence of stresses developed as a result of mechanical loading during service. Surface damage was observed at four other locations around the circumference of the rim, probably as a result of operational use or maintenance handling activities, however, no other crack defects were found in the wheel.

Material tests conducted on the failed wheel L4 and mating wheel R4 found they complied with AAR[6] standards and showed no evidence of defects that exceeded material standards or manufacturing specifications.

[4] Three phase alternating current
[5] Refer to Appendix A - Technical Analysis
[6] Association of American Railroads

Wheel maintenance history

DEDI procedures specify that wheel inspections are carried out over a workshop pit once per month. The inspections include a visual examination of wheel tread and rim surfaces where a fitter looks for basic flaws, imperfections, impact damage and defect limits. The condition of each wheel is recorded on a wheel inspection sheet and details entered into a maintenance management system database[7].

An examination of maintenance records found that inspections and servicing of wheels on SCT 008 had been carried out according to the operator's procedures. Where defect limits were exceeded for flange thickness or wheel tread hollowing, the wheel treads and flanges were machined to restore the correct wheel profile. Major servicing details for wheels on SCT 008 before the failure of wheel L4 are shown in Table 1.

Table 1: Extracts from DEDI maintenance history for locomotive SCT 008

Date	L4 Dia. (mm)	R4 Dia. (mm)	Total travelled (km)	Distance since last machining (km)	DEDI Comment
15/04/2008	1068	1068	10	-	New locomotive (wheel profile WPR 2000)
9/10/2008	1059	1059	108,407	108,397	Wheel turn performed at Motive Power Centre (Dry Creek) and profiled to ANZR-1. Hollow Tread on Wheel - R3
31/01/2009	1046	1046	181,793	73,386	Drivers left handbrake on, when set up as dead unit for hauling back to Adelaide. Wheels hotter than others. Appear and spin OK. Driver said no flats on wheels, but must be inspected. Wheel full profile completed at 'A' inspection 8/2/09 and OK.
12/09/2009	1040	1041	335,771	153,978	All flanges restored to 28mm x 7/8" Remove tread hollowing
30/01/2010	1024	1024	443,345	107,574	Machine all 6 wheel sets account diameter variations & tread hollowing. Correct diameters on "A" bogie and machine "B" bogie to restore flanges.
12/01/2011	1014	1014	695,839	252,494	Machine out tread hollowing and reinstate chamfers to rim face on all wheels, flange heights reduced.
28/05/2011	1007	1009	801,273	105,434	Catastrophic failure of wheel L4 at Fisher SA

Following wheel machining to remove tread hollowing on 12 January 2011, visual inspections and measurements of all wheels were completed at Dry Creek, South Australia on 2 April 2011 and Altona, Victoria on 12 March, 26 March, 18 April and 3 May 2011, the last inspection being conducted 25 days before the failure of wheel L4. At each of these inspections no wheel defects were found and recorded for the wheels on locomotive SCT 008. However, dust and other contaminants on the back rim surfaces may have concealed evidence of a crack on wheel L4.

Between April 2008 and January 2010 four services were carried out for the machining/re-profiling of all wheels. Through this period SCT 008 travelled an average distance of about 253,000 km per annum.

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7 The maintenance management system database provides a common repository for maintenance records across multiple maintenance facilities.

In the following 12 months, SCT 008 travelled a further 252,000 km where no wheel machining was carried out, however 24 diameter measurements of all wheels were recorded by data logging equipment. The average reduction in wheel diameters for all wheels over this period was 8-12 mm and the reduction of diameters of wheels on the same axle varied by no more than 4 mm (wheels L3/R3 22 April 2010). When wheel L4 fractured on SCT 008, the wheel diameter was measured at 1007 mm. The condemn diameter was specified at 991 mm.

Wheel profile

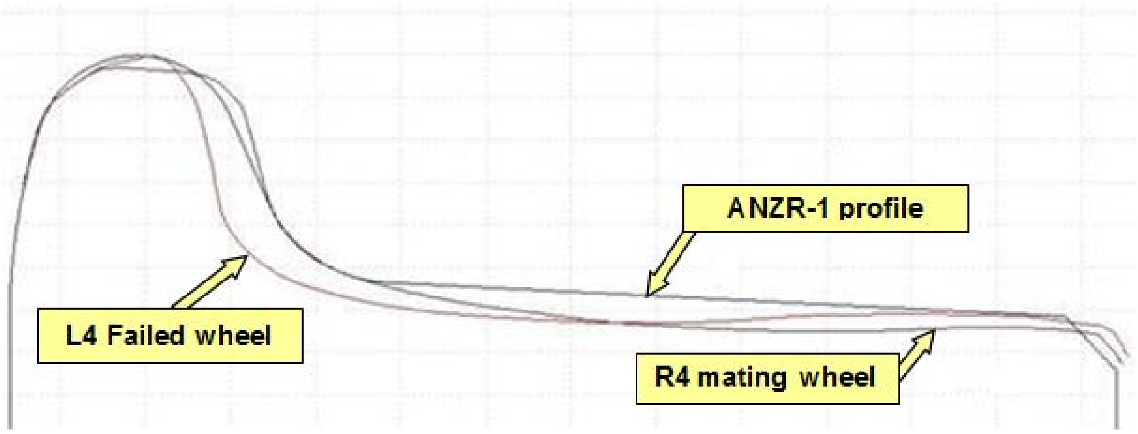
Locomotive wheel treads are machined with a conical profile to provide improved guidance and to maximise life. Wheel flanges are a defence in minimising the risk of derailment. Generally the wheel profiles and rim widths are specified by the railway track manager or owner. For operation on the ARTC network the ANZR-1 wheel profile is recommended by the Australian Standard AS 7514.1 Railway rolling stock - Wheels - Part 1 - Locomotive.

From new, WPR 2000 profiled wheels were installed on locomotive SCT 008. On 9 October 2008, after travelling 108,407 km, the wheels on SCT 008 were re-profiled from the WPR 2000 to ANZR-1 profile as recommended by the Australian Standard. The re-profile was to provide an improved dynamic response for locomotives tasked to intermodal operations.

SCT 008 wheel profiles for the failed and mating wheels were measured using a Miniprof®[8] instrument and these dimensions were each overlayed and compared with the original ANZR-1 profile. The traced profiles (Figure 4 and 5) showed that there was an increased level of wear on the wheel flange of failed wheel L4 when compared to the mating wheel R4. Flange thickness measurements showed that L4 was 22.5 mm thick and had worn 5.4 mm more than R4 (27.9 mm). The reduced flange thickness of wheel L4 was however greater than the minimum thickness and specified condemn limit of 19 mm. DEDI reported that about 20% of the SCT class fleet have wheels with reduced flange thicknesses.

The increased level of flange wear on L4 indicated that there was an asymmetrical tracking bias9 estimated to be about 19-20 mm towards the flange of wheel L4. DEDI indicated this may have been caused by slight variances in wheel diameter (for wheels mounted on the same axle) as a result of the machining and measurement accuracy of the wheel lathe. Reports by DEDI and the IRT noted that the "… in-service loading conditions which resulted in increased flange wear may have also contributed to the high stress levels in the rim". The ATSB found no additional evidence to indicate that the increased flange wear contributed to the failure of the wheel on SCT008.

Figure 4: Locomotive SCT 008 overlaid profile comparisons of wheels L4 and R4 with ANZR-1 reference profile



8 Precision instrument used for the measurement of rail wheel profiles where the data is analysed on a computer.

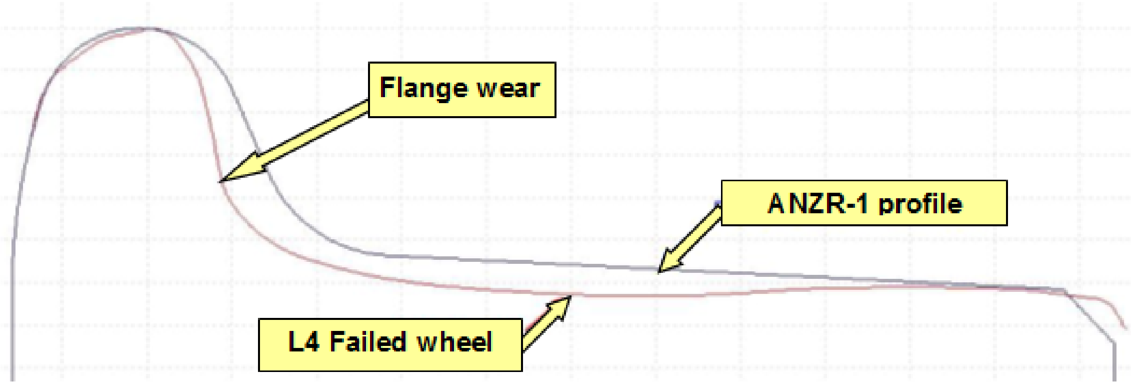
9 An asymmetrical tracking bias is caused by a variation of the wheel diameters fixed to the same axle.

The maintenance record for SCT 008 showed that on 30 January 2010 the wheels on 'A' bogie (axles 1, 2, 3) were machined for tread hollowing and wheels on the 'B' bogie (axles 4, 5, 6) were machined for flange restoration. The differing wheel wear types that were specific to each bogie were indicative of a tracking bias and the asymmetrical flange wear found on the wheels of the 'B' bogie.

Locomotive SCT 008 had previously been workshopped four times for wheel machining since entering service. Over the life of wheel L4, re-profiling to remove tread hollowing and to restore flange height had reduced the overall diameter from 1068 mm when new to 1007 mm at the time of failure. The diameter of mating wheel R4 was measured at 1009 mm at this time.

The maximum distance travelled before re-machining of wheels on an SCT class locomotive (prior to the failure of L4 on SCT 008) was recorded at 313,471 km. Locomotive SCT 008 had travelled a total of 801,270 km and had all wheels re-profiled 105,434 km before the failure of wheel L4.

Figure 5: Locomotive SCT 008 overlaid profile comparison of wheel L4 and with ANZR-1 reference profile showing greater flange wear



Rolling contact fatigue

Cracks in locomotive wheels can originate from stress points found in the work hardened tread region and are associated with rolling contact fatigue. Ultrasonic testing of other wheels on SCT 008 (post 28 May 2011) found evidence of rolling contact fatigue (RCF) subsurface cracking in wheel L3 that had initiated at an inclusion[10] located about 10 mm below the tread surface.

The locomotive wheels fitted to the SCT class locomotive were heat treated to within a defined hardness range to reduce the amount of tread wear. The reduced level of wear usually increases the distances that can be travelled, consequently extending the service intervals between wheel re-profiling.

Stress concentration points in locomotive wheels (under constant cyclic loading) generally occur in a relatively consistent area within the wheel rim (that is, consistent depth below the tread). Wheels that are subjected to higher and prolonged service loadings are at greater risk of developing rolling contact fatigue and subsurface cracks, due to extended periods of stress concentration in the same area. The risk increases further if the stress concentration coincides with a subsurface defect. If undetected, cracks may develop from subsurface defects and can result in catastrophic wheel failure unless they are removed.

When a wheel is machined, tread material is removed to restore the correct wheel profile. As the rail contact point has changed (in relation to the wheel rim), due to a reduction in wheel diameter, so too does the location of stress concentration points within the rim. It is likely that by increasing the frequency[11] of wheel set machining, stress concentration points will progressively move

[10] An inclusion is a subsurface defect created during the steel manufacturing process.

[11] Downer EDI Rail, Failure report CFR00723 Rev A, SCT locomotive wheel failure analysis.

deeper into the rim region. This in turn, may reduce the risk of prolonged stress concentration developing into sub-surface related defects and subsequently propagating into large cracks and affecting the integrity of the wheel.

Defects in wheels of other SCT class locomotives

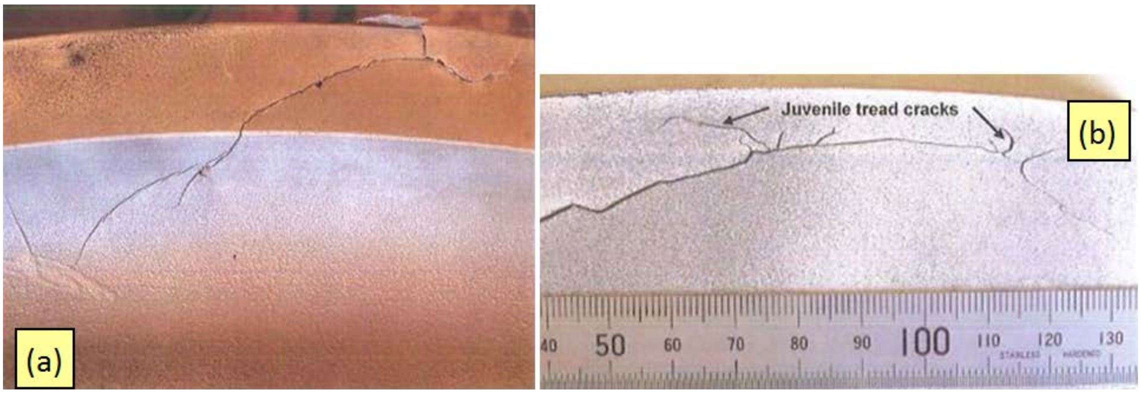
During routine maintenance on locomotive SCT 006 in June 2010, wheel L3 was found with a fatigue crack that had initiated from an inclusion located 8 mm below the tread surface. The crack was about 180 mm in length radiating towards the hub (Figure 6). No other cracks were identified within the wheel.

An investigation was commenced by SCT Logistics and DEDI. The defective wheel was removed from the axle and subjected to a laboratory based metallurgical evaluation. Testing of the wheel included visual, non-destructive, chemical, hardness and micro structural examinations.

Results of the investigation found:

- The wheel rim was well above condemning thickness.
- Ultrasonic scans of the wheel rim, web and boss found no additional internal defects.
- The rim hardness was within the specified Brinell[12] hardness range.
- The crack origininated 8 mm below the wheel tread surface and 55 mm from the rim face.
- Circumferential cracking at the tread extended for about 140 mm and progressed to a depth of about 75 mm from the rim face.
- Fatigue was the cracking mechanism as the wheel had been subjected moderate levels of cyclic stresses.
- It was likely that with wheel wear the defect came closer to the rolling contact stress zone and the fatigue cracking was initiated.
- The internal fatigue crack originated from a material defect that was probably present in the steel billet prior to the manufacture of the wheel.

Figure 6: SCT 006 magnetic particle indications (a) - at rim and transition face. (b) – juvenile cracks branching towards wheel tread



Photos extracted from ALS Material Evaluation Report No 4980-908/1

The material analysis of wheel L3 for chemical composition, hardness and microstructure revealed that it generally conformed to AAR M201 Class B[13] however metallurgical defects had contributed to the fatigue cracking within the wheel.

Examination of available records by the ATSB established that visual examinations, measurements and re-profiling of all SCT class locomotive wheels was an established part of

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[12] The Brinell hardness test used to determine the hardness of metals and other materials.

[13] Association of American Railroads specification for carbon and alloy steel castings for locomotive equipment.

regular maintenance and continued through until the failure of wheel L4 on SCT 008 on 28 May 2011. Following the occurrence, additional ultrasonic and visual examinations were undertaken. These examinations established further instances of wheel defects in SCT 003, SCT 005, and SCT 009. The total distances travelled by each of these locomotives, since commissioning, was 650,000 km, 675,000 km and 648,000 km respectively.

The ultrasonic testing revealed a subsurface crack 75 mm x 3 mm in wheel R5 on SCT 003 and visual examinations revealed wheel tread surface cracks in wheel R1 on SCT 005 and wheel R6 on SCT 009. The wheels were re-profiled to remove the defects and returned to service. Another 38 mm crack was detected in wheel L3 on SCT 009 and this wheel was subsequently scrapped. Wheel R6 from locomotive SCT 013 was found with a chipped flange and this wheel was also scrapped. All wheels with detected flaws had not reached their minimum diameters (condemning limit).

Nine LDP class locomotives that were manufactured by DEDI were fitted with the same type of wheels as those fitted to the SCT class locomotives. Following the discovery of the failures of wheels on SCT class locomotives, all wheels of the LDP class locomotives were ultrasonically tested but no defects were found.

Safety analysis

The investigation found that wheel L4 failed as a result of a fatigue crack initiating from a small indentation on the lower back rim face corner.

Wheel material

The wheels used on the SCT class locomotive fleet were manufactured from Class BM grade steel. Class BM steel is micro-alloyed steel based on AAR specification M-107/M-208 (Wheels, Carbon Steel) for Class B material. Metallurgical analysis of L4 and R4 wheels showed the steel properties to be consistent with the specification for Class BM grade wheels.

Class BM grade wheels are used on various locomotives operating in Australia. The steel has high hardness resulting in reduced tread wear and increased distances between wheel machining. However, running longer distances without machining can increase the risk of rolling contact fatigue cracks developing due to cyclic loading. Under these conditions, subsurface defects or imperfections can grow into fatigue cracks and may result in complete wheel failure if undetected.

Ultrasonic testing found subsurface cracks in wheels from the SCT fleet, but not in LDP class locomotives fitted with the same type of wheel (also maintained by DEDI). The LDP class locomotives were similar to the SCT class, but had not been exposed to the same levels of high speed cyclic loading.

Considering the apparent higher levels of subsurface cracking in wheels on the SCT fleet, DEDI recommended more regular wheel machining to manage stress concentrations within the wheel and reduce the risk of subsurface defects becoming large cracks. In addition, DEDI recommended that, for new wheels, SCT use NUVAN class material. NUVAN has a higher vanadium content resulting in higher fracture toughness and has been specified for new locomotives built for other rail operators.

Wheel inspection

Monthly inspections identified tread hollowing and flange wear on locomotive SCT 008. When necessary, the wheels were machined to ensure the wheel profiles were maintained within the required tolerances. In each case, the inspection of wheels was visual only.

Examination of the failed wheel (L4) showed a crack emanating from a pre-existing surface indentation. Similar surface damage was evident at four other locations around the circumference of the rim. However, neither the crack nor the surface damage was identified during visual wheel inspections, possibly due to dust and other contaminants concealing visual evidence of defects.

AAR guidelines recommend that ultrasonic testing be carried out on each wheel following machining. The intent is to identify any subsurface cracks. Considering the likelihood that the existing inspection regime may not detect wheel defects that increase the risk of wheel failure, DEDI recommended that SCT increase the level of locomotive wheel visual inspections and perform ultrasonic testing of wheels after they have reached mid-life (400,000 km). Thereafter, SCT class locomotive wheels will be ultrasonically tested at each re-machining. (consistent with the AAR guidelines).

Findings

While travelling near Fisher, South Australia on Saturday 28 May 2011, freight train 5MP9 experienced a catastrophic failure of a locomotive wheel. The train stopped about 1.8 km later without derailing.

From the evidence available, the following findings are made with respect to the failure of locomotive wheel L4 on SCT 008. 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 safety factors

- A small indentation on the lower back rim face corner of wheel L4 acted as a fatigue crack initiation point.
- Wheel L4 fractured due to the initiation and propagation of a fatigue crack. After the crack had grown to critical size, the wheel was unable to sustain the operational stresses, resulting in an overload of the remaining section which caused a complete fracture and disintegration of about half of the wheel disc and rim.
- **The wheel inspection processes prior to the failure of locomotive wheel L4 on SCT 008 were not effective in detecting surface damage or cracks. [Safety issue]**
- The failure of wheel L4 on SCT 008 was influenced by stresses that had developed as a result of high in service mechanical loading.
- **Subsurface cracks appeared to be more common on wheels made with Class BM grade steel while operating under conditions of high speed cyclic loading, such as the SCT class locomotives. [Safety issue]**

Other key findings

- Wheel profile measurements indicated an asymmetrical tracking bias of about 20 mm where wheel L4 had sustained more flange wear.
- Residual stress measurements of wheels L4 and R4 indicated that no overheating of the material had occurred.
- Material tests of wheels L4 and R4 found they complied with AAR standards and specifications.

Safety issues and actions

The safety issues identified during this investigation are listed in the Findings and Safety issues and actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Wheel inspection processes

Number:	RO-2011-009-SI-01
Issue owner:	SCT Logistics
Operation type:	Train operator
Who it affects:	All owners and operators of locomotives fitted with Class BM grade wheels that are operated in conditions of high in service mechanical loadings

Safety issue description:

The wheel inspection processes prior to the failure of locomotive wheel L4 on SCT 008 were not effective in detecting surface damage or cracks.

Proactive safety action taken by SCT Logistics

To improve detection of surface damage and cracking of wheels fitted to the SCT class of locomotive, SCT has advised the following actions:

- Increase the level of visual inspections at wheel turning and during scheduled maintenance intervals, principally for evidence of impact damage.
- Perform ultrasonic testing at each wheel machining after travelling 400,000 km, principally for evidence of cracking .
- Where integral ultrasonic testing facilities are not available at wheel machining facilities, testing should start after midlife of the wheel when risk of wheel cracking increases.

Action number:	RO-2011-009-NSA-024
Action status:	Adequately addressed
ATSB response:	The ATSB is satisfied that the action taken by SCT Logistics addresses this safety issue.

Class BM grade steel

Number:	RO-2011-009-SI-02
Issue owner:	SCT Logistics
Operation type:	Train operator
Who it affects:	All owners and operators of locomotives fitted with Class BM grade wheels that are operated in conditions of high in service mechanical loadings

Safety issue description:

Subsurface cracks appeared to be more common on wheels made with Class BM grade steel while operating under conditions of high speed cyclic loading, such as the SCT class locomotive.

Proactive safety action taken by SCT Logistics

To reduce the risk of further failures with wheels fitted to the SCT classes of locomotives, SCT has advised the following actions:

- Update the wheel management policies to require a more regular wheel machining regime across the fleet, in the range 130,000 km – 150,000 km, removing 4 mm per turn.
- For future wheel purchases, particularly for high speed operations specify NUVAN class vanadium modified steel that provides increased fracture toughness.

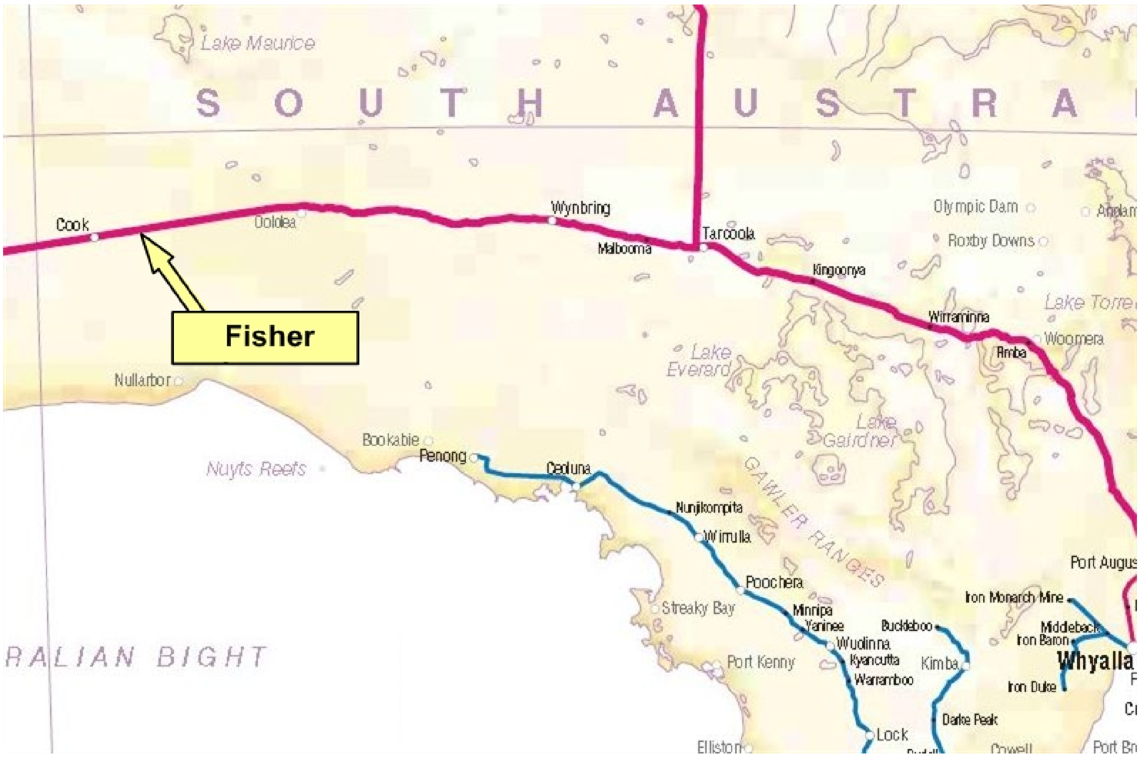
Action number:	RO-2011-009-NSA-025
Action status:	Adequately addressed
ATSB response:	The ATSB is satisfied that the action taken by SCT Logistics addresses this safety issue.

General details

Occurrence details

Date and time:	28 May 2011 – 0145 CST	
Occurrence category:	Rolling stock Irregularity	
Primary occurrence type:	Wheel/Axle Failure	
Location:	The incident occurred on the interstate main line near Fisher in South Australia about 350 km west of Tarcoola (Figure 7).	
	Latitude: 30º 32.11' S	Longitude: 131º 04.34' E

Figure 7: Map showing location of occurrence near Fisher, South Australia



Source: NATMAP Railways of Australia

Train details

Train operator:	SCT Logistics	
Registration:	5MP9	
Type of operation:	Intermodal freight	
Persons on board:	Crew – 4	Passengers – N/A
Injuries:	Crew – 0	Passengers – N/A
Damage:	Minor	

Train crew information

Train drivers:	The train crew consisted of two sets of two drivers provided under contract to SCT Logistics (SCT) by Genesee and Wyoming Australia. The two crews were working rotating shifts with one crew driving while the other was resting. The resting crew were accommodated in a fully equipped crew van marshalled near the front of the train. The drivers operating the train at the time of the incident were appropriately qualified, assessed as competent and medically fit for duty.

Track

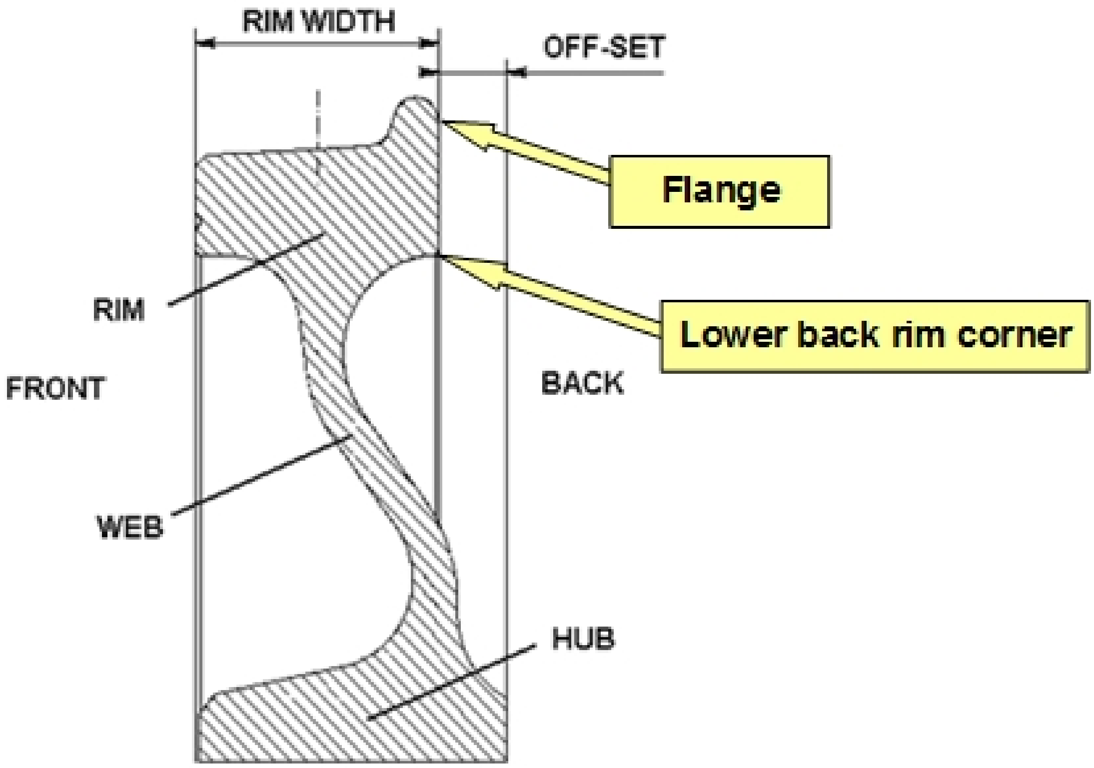
Track:	The track through this location was constructed on a limestone rock and earth base surrounded by sparse bluebush and other low level vegetation. The track was straight near the incident site with the train transitioning from a near level plane into a 1 in 300 ascending grade. The track structure consisted of continuously welded 47 kg/m rail secured to concrete sleepers with resilient fasteners and supported by a ballast bed having a minimum depth of 250 mm. The sleepers were spaced at approximately 667 mm centres.

Appendix A –Technical Analysis

Examination fractured wheel L4

An examination of components from the trailing bogie was carried out at the DEDI maintenance facility in Newport, Victoria. The fractured[14] L4 and mating[15] R4 wheels were pressed off the axle resulting in the remaining part of fractured wheel L4 breaking through the web into three major sections (Figure 8).

Figure 8: Wheel terminology



Source: RISSB - Standards Australia

All fractured sections of the wheel and the mating wheel were forwarded to the IRT for detailed inspection and testing. An ATSB investigator photographed, measured and documented wheel details and discussed testing requirements/analysis with specialists from the IRT laboratory.

The first segment that separated from wheel L4 comprised about 50% of the wheel circumference (Segment A in Figure 9). This piece was recovered from the centre of the track near the point of failure near Fisher, SA.

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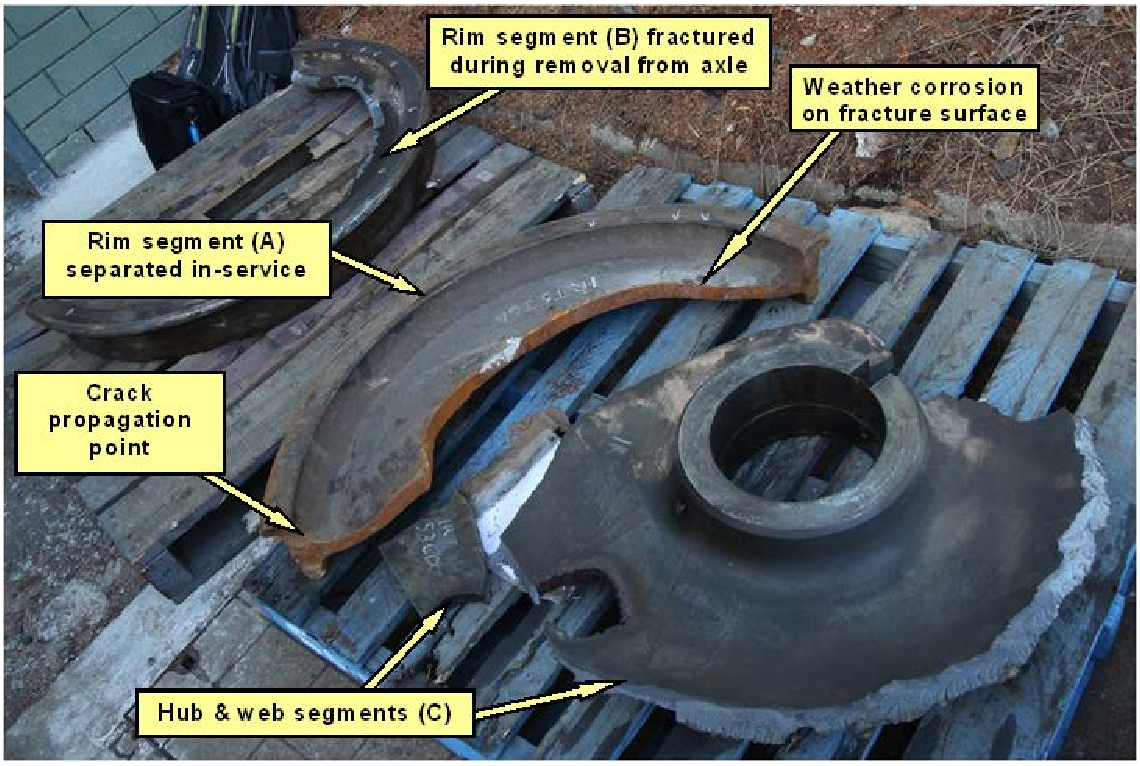
14 Fractured wheel identification L4 (left 4) serial # 21052-05-07 CSC BM

15 Mating wheel identification R4 (right 4) serial # 21094-05-07 CSC BM

Figure 9: SCT 008 fractured wheel L4 (ID# 21052) after removal from the axle



Source: ATSB

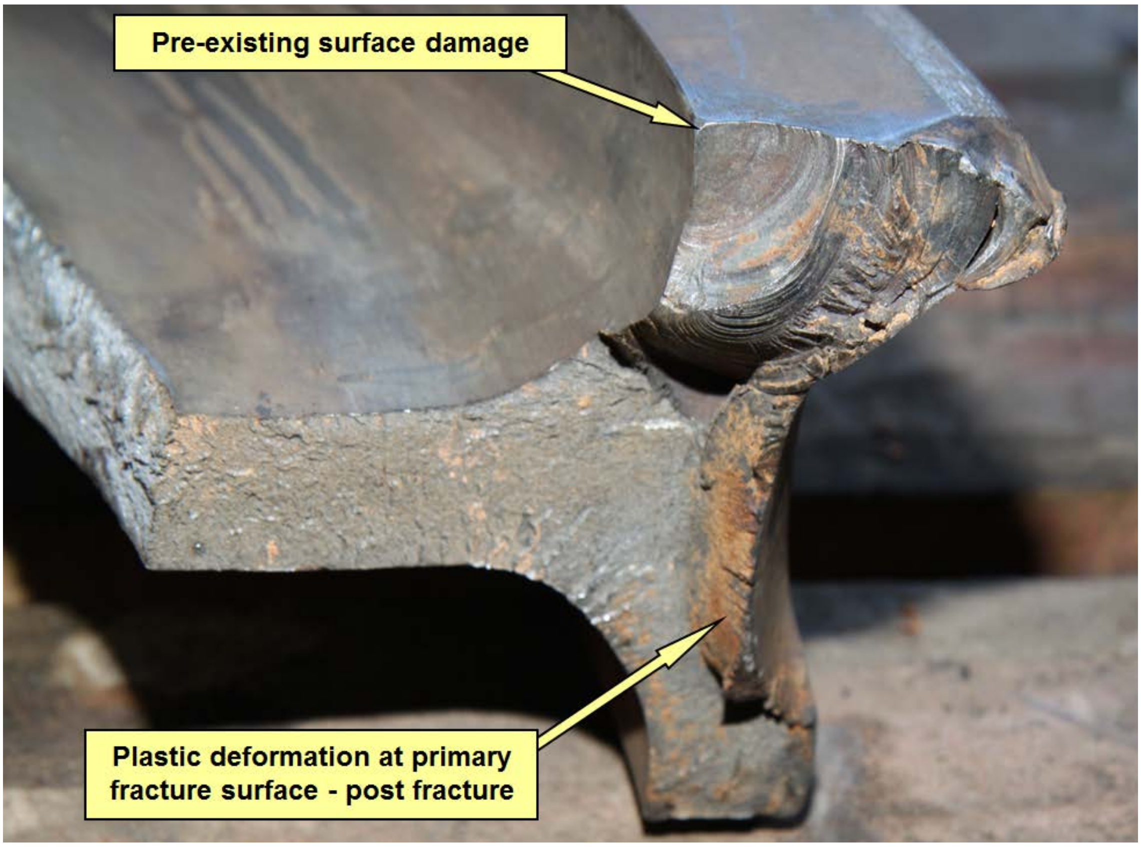
Figure 10: Detached section (A) showing pre-existing surface damage on corner of back rim face and radial propagation point of the fatigue crack

Source: ATSB

The separated segment (A) showed significant corrosion on the fracture surface. However this was associated with post event weather exposure and had not contributed to the failure of the wheel.

A large fatigue crack on the primary fracture surface had initiated from the lower back corner of the rim face (Figure 11) where there was evidence of pre-existing surface damage in the form of a small indentation measuring about 1 mm in depth (Figure 10 and 11). The indentation was visible on both pieces of the fractured rim.

Figure 11: Detached section (A) showing pre-existing surface and post fracture damage



Source: ATSB

The IRT noted:

> At the point of wheel failure, the fatigue crack measured approximately 50 mm in a radial direction along the back rim face, 35 mm in an axial direction along the inner rim surface (*Figure 10*), and approximately 45 mm from the lower corner of the back rim face towards the tread at an angle of 45°.

Surface damage at four other locations was observed around the circumference of the rim, probably as a result of operational use or maintenance activities. Magnetic particle testing around the back rim face found no evidence of fatigue coincident with the surface damage or elsewhere on the rim.

An examination on the mating wheel R4 (ID# 21094) found no evidence of surface damage and both wheels showed no discolouration to indicate overheating of the rim or web surfaces.

Ultrasonic inspection of wheels

Ultrasonic testing of new and in service railway wheels is carried out to assess steel cleanliness[16] and to detect manufacturing defects and subsurface fatigue cracking through the tread area. Defects found during ultrasonic tests are shown as reflections and are measured to assess whether or not the defects are within acceptable limits.

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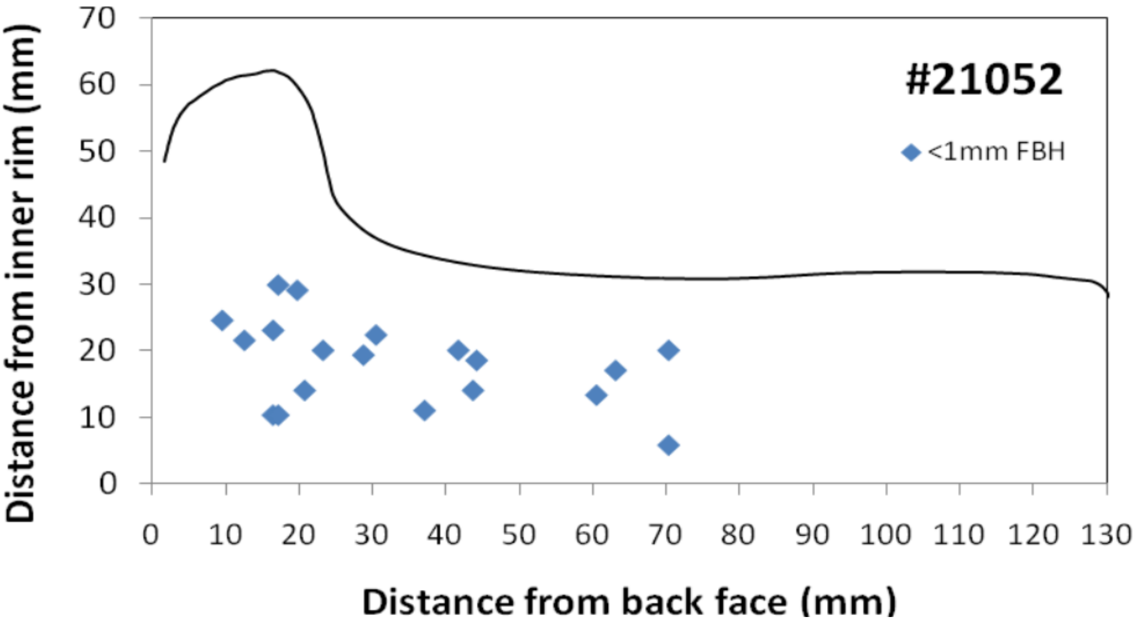
16 The composition, size, number and distribution of inclusions determine the cleanliness of steel.

The IRT ultrasonically scanned SCT 008's rims on wheels L4 and R4 every 1.4 mm of rim circumference and the results were assessed against the AAR standard M-107/M-208[17]. Failed wheel L4 showed a small number reflections that were less than 1.0 mm in size[18] and these were within the acceptance criteria (Figure 12).

Figure 12: Distribution of ultrasonic reflections on failed wheel L4 (#21052)



Mating wheel R4 contained a greater number of reflections below the 1.0 mm size and a small number between 1.0 mm – 1.6 mm in diameter (Figure 13).

Although the rims on both wheels varied in cleanliness with the failed wheel (L4) showing less and smaller reflections than the mating wheel (R4), both complied with the AAR material standard applicable at the time of manufacture. The IRT found the level of steel cleanliness of wheel L4 was not related to its failure.

Following the failure of wheel L4 on SCT 008, DEDI developed specification CPS00690[19] for the ultrasonic testing of the wheels fitted to the SCT class locomotive fleet. This specification was developed and is in accordance with the AAR standard M-107/M-208 and recommends that all wheels are ultrasonic tested after wheel turning to identify sub-surface cracks.

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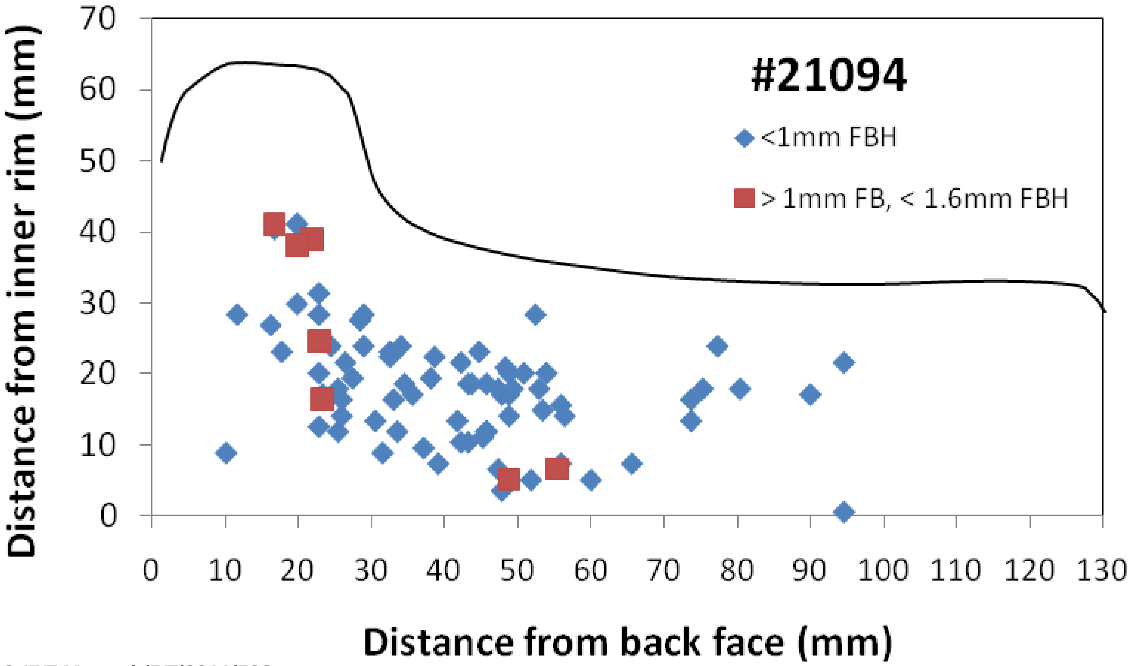
[17] Association of American Railroads Specification M-107 / M-208 - Wheels, Carbon Steel.

[18] Ultrasonic measuring equipment is calibrated using standard hole blocks (flat bottom hole – FBH) where reflected high frequency ultrasonic signal values are used as a reference for setting the controls of the ultrasonic instrument.

[19] CPS00690 Wheel Ultrasonic Test Specification (GT46C-ACe Locomotive Wheels)

Figure 13: Distribution of ultrasonic reflections on mating wheel R4 (#21094)



Metallurgical analysis

The IRT cut cross sections of the failed (L4) and mating (R4) wheels from SCT 008 and carried out chemical analyses, macro examinations and mechanical tests.

Cross sections were taken and prepared for macro examinations of the wheels. Test results showed there were no abnormalities associated with steel quality or evidence that either wheel had been subjected to overheating.

When both wheels were tested for chemical composition against the standard, EN13262 *Wheel sets and bogies - Wheels - Product Requirements*, they were found to be compliant.

Wheel rim hardness

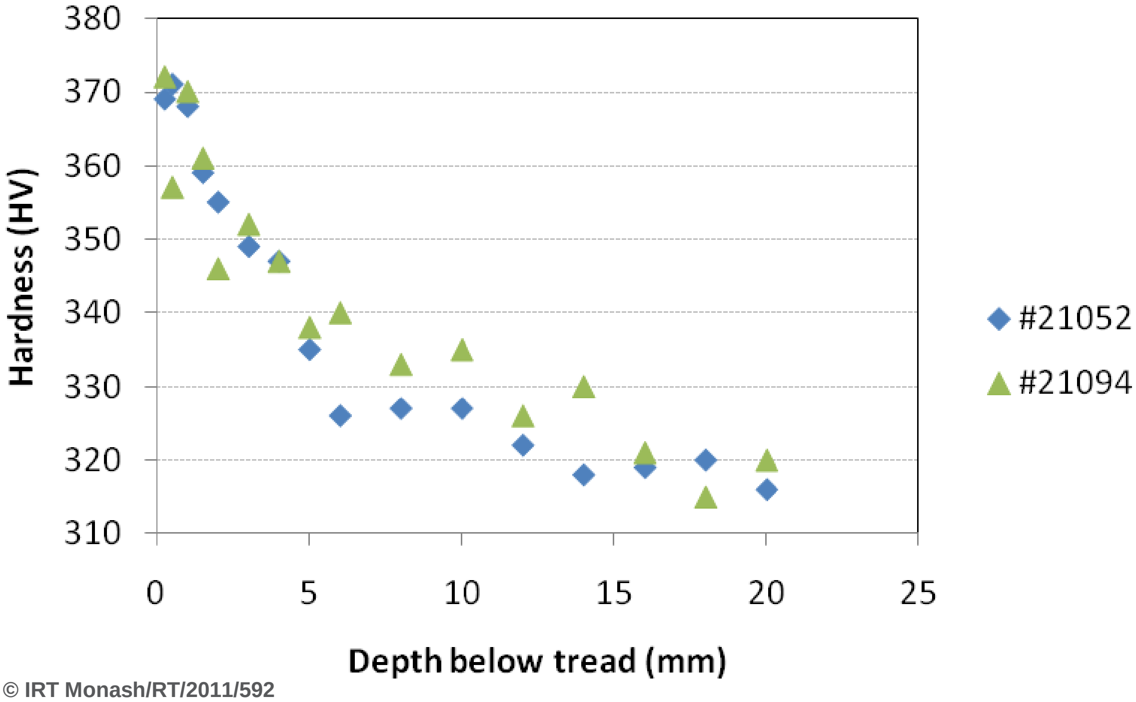
The wheel material used on the SCT class was manufactured from Class BM grade steel. This steel has high hardness which results in very low rates of tread wear, allowing locomotives to travel greater distances before requiring wheel turning.

The IRT conducted hardness tests on rim sections of SCT 008 wheels L4 (ID #21052) and R4 (ID #21094) (Figure 14). The tests showed that near the centre of the tread-line work hardening had occurred to a depth of a between 5 - 7 mm below the tread surface. The distribution of hardness in the lower sections of both rims showed no inconsistencies and was similar for both wheels.

Hardness and tensile tests found there were no unexpected variations in values when compared with a specification for Class BM wheels.

Tensile tests were carried out on specimens of L4 and R4 rim sections. Measurements were taken about 15 mm below the worn tread surfaces and results were slightly below the specified minimum values. This was expected, due to the location of samples on the worn wheel when compared to that specified for a new wheel.

Figure 14: Distribution of hardness (Vickers 10 kg) for wheels L4 and R4



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Residual Stress

Non-destructive tests were carried out to determine the distribution of residual stress between the back and front rim faces of SCT 008 wheels L4 and R4. Tests for failed wheel L4 were carried out on two rim sections near the circumference mid points. Tests for mating wheel R4 were carried out at 90° intervals. Each test consisted of a series of readings taken at 5 mm increments commencing 10 mm from the inner corner of the back rim face and towards the wheel flange over a distance of 15 mm.

The tests found that there was some relaxation of residual stress in wheel L4 following its failure and the results may not have been indicative of the condition of the wheel before failure. The radial distribution of residual stress in wheel R4 was consistent with a wheel that had not been exposed to significant thermal loading. Stress values varied nearest the tread section, however this may be attributed to the extent of work hardening through rolling contact with the rail.

Residual stress readings from the lower rim region of mating wheel R4 showed a negative offset which is consistent with the higher levels of metallurgical inclusions as these inclusions have a tendency to scatter the ultrasonic signals.

The residual stress values near the tread for failed wheel L4 were similar to the mating wheel R4, however variations that existed in the lower rim area of wheel R4 were most likely associated with a greater number of inclusions found through ultrasonic testing.

Destructive residual stress tests were carried out at a position 4 mm up from the back inner rim face of both wheels. Tests on mating wheel R4 showed no abnormal results while tests carried out near the fatigue crack initiation point on wheel L4 indicated that there was some relaxation in the circumferential direction as a result of the failure. Overall, the residual stresses in both wheels were similar. Due to differences in the cleanliness levels of wheels L4 and R4 it was not possible to compare the residual stress distribution in the lower regions of the rims.

It is likely that the fatigue crack initiation point in wheel L4 commenced at the small indentation (Figure 10) but was further influenced by stresses that had developed as a result of mechanical loading during service. Variations in residual stress distribution may have influenced the direction of crack propagation.

Sources and submissions

Sources of information

The sources of information during the investigation included:

- Downer EDI Rail
- Office of the National Rail Safety Regulator
- Public Transport Safety Victoria (PTSV)
- SCT Logistics
- The Australian Rail Track Corporation

References

ALS Material Evaluation Report No. 4980-0908/1 (2010), Metallurgical evaluation of a cracked locomotive wheel.

Association of American Railroads (2004), Manual of Standards and Recommended Practices, Section G, Specification M-107/M-208, Wheels, Carbon Steel.

Association of American Railroads, AAR M-201, Steel Castings.

Downer EDI Rail, Failure report CFR00723 Rev A, SCT locomotive wheel failure analysis.

EN13262, Railway applications, Wheel sets and bogies - Wheels - Product Requirements.

Monash University Institute of Railway Technology, August 2011, Investigation of a failed SCT locomotive wheel, Report No. Monash/RT/2011/592.

RISSB Glossary of Railway Terminology – Guideline

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

- Downer EDI Rail
- Office of the National Rail Safety Regulator
- SCT Logistics
- The Australian Rail Track Corporation

Submissions were received from

- Office of the National Rail Safety Regulator
- SCT Logistics
- The Australian Rail Track Corporation

The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

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.

Australian Transport Safety Bureau

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Investigation

ATSB Transport Safety Report
Rail Occurrence Investigation
Failure of wheel on locomotive SCT 008
near Fisher, South Australia, 28 May 2011
RO-2011-009
Final – 3 July 2013