SA Newsletter

June 2009

ENGINEERS AUSTRALIA

RTSA

NEXT CHAPTER MEETING:

Thursday 2nd July

Adelaide's Belair Track Upgrade

by

Phil Agnew of Department for Transport, Energy & Infrastructure, SA

Venue: Engineering House, 11 Bagot Street, North Adelaide

Light Refreshments from 5.30pm, meeting commences 6.10pm

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Chapter Meetings

Thursday 2 July 2009

Chapter meeting, 11 Bagot St, North Adelaide – Belair Line Upgrade, by Philip Agnew.

Thursday 6 August 2009

Joint Chapter meeting with Mechanical Groups, 11 Bagot St, North Adelaide – 'Wheel Squeal' by Kirsten Alexander and Carolyne Southern.

Thursday 3 September 2009

Joint Chapter meeting RTSA/PWI hosted by IRSE at Gil Langley Room, Adelaide Oval. Topic to be confirmed.

Thursday 1 October 2009

Chapter meeting, 11 Bagot St, North Adelaide.

Thursday 22 October 2009

PWI Quiz Night, details to follow shortly.

Thursday 5 November 2009

Chapter meeting, venue to be confirmed – ARTC Network Enhancement investment update by Ben Leske.

Tuesday 1 December 2009

Annual dinner meeting + AGM, Hyde Park Tavern.

Publisher

This newsletter is a publication of the South Australian Chapter of the Railway Technical Society of Australasia, Engineering House, 11 Bagot Street, North Adelaide SA 5006. Opinions expressed within are not necessarily those of the Chapter, Society or Editor.

Contributions

Contributions, including news, opinions, or letters to the editor, are always welcome. Send material by e-mail to sa-editor@rtsa.com.au

Continuing Professional Development

Engineers Australia members are reminded that attendance at RTSA technical meetings contributes towards CPD requirements. Each RTSA technical meeting generally has a value of 1 CPD point.

RTSA Website

The RTSA website www.rtsa.com.au has details of RTSA activities, including future meetings and reports from past meetings, for all Chapters.

Membership

Information for potential new members and an application form may be found at www.rtsa.com.au.

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Newsletter Dispatch

Dispatch of the newsletter is undertaken by Steve Torok. Contact Steve on storok@tge.com.au if you have any problems receiving newsletter electronically or in hard copy, or change your e-mail address.

Coming Events

Study Tour on Railway Engineering

The NSW Chapter has received an encouraging number of applications for its Study Tour on Railway Engineering (STORE) to Asian Metro Systems, which will take place on 12th – 23rd September 2009, visiting Singapore, Kuala Lumpur, Shanghai, Beijing and Hong Kong. Places are limited so see the link below for more information and secure your spot:

http://rtsa.com.au/assets/2009/04/store-2009.pdf

Travelling to Mars – Engineers Australia Distinguished Speaker

Engineers Australia South Australia Division, South Australia Science Teachers Association (SASTA) and the Sir Ross and Sir Keith Smith Fund invite you to attend a presentation by James Reilly at the National Wine Centre on 8th July 2009.

James Reilly will speak about his involvement at NASA and the engineering challenges of designing the Mars mission. These challenges involved human factors, spacecraft issues, Mars base considerations and scientific preparations for the search for water and possible signs of life. He will reflect on the current state of preparations for the Mars mission, and issues that still need to be resolved before a mission can take place.

Date: Wednesday 8th July 2009

Time: 5.30pm for 6.00pm start

Venue: National Wine Centre, Corner of Botanic and Hackney Roads

Cost: FREE

RSVP: by 3rd July 2009 to Norma Cowan, Technical Program Officer

Email: ncowan@engineersaustralia.org.au

Phone: 8267 1783

Registration is essential as numbers are limited. Your registration will be confirmed via email.

AusRail Plus 2009, Adelaide

Between 17th-19th November, Adelaide will host the largest annual rail event in the Asia Pacific region, AusRail Plus, at the Adelaide Convention Centre. With trade exhibitions, networking functions and a program of international speakers, this 3-day conference will be the biggest rail event of 2009.

Full details can be obtained from www.ausrail.com/informaoz/AusRAIL/

See below re complimentary attendances available to RTSA's younger members.

News

SA Chapter Meeting May 7th, 2009

The last Chapter meeting saw a presentation on the topic of *Rail Maintenance Developments in Heavy Haul by Peter Mutton of Monash University.* A copy of this presentation is included at the end of this newsletter for those of you unable to attend.

For Younger Members – Complimentary Attendance at AusRail Plus 2009

RTSA is pleased to be able to offer a limited number of complimentary places at AusRail Plus 2009 to its younger members (up to age 35).

Complimentary attendance covers full registration (including social functions), but not travel or accommodation. In the event that the number of applications exceeds the available places, a selection process will take place.

Applications, outlining on not more than one page details of your background, involvement in the rail industry, and how you envisage benefiting from attendance, should be sent to sa@rtsa.com.au by 31 July 2009.

Chairman's Chatter

Peter Mutton's presentation at our June Chapter meeting, on Rail Maintenance Developments in Heavy Haul, highlighted how innovative technological initiatives are enhancing the productivity and efficiency of rail transport.

Of particular note were the use being made of instrumented ore cars to provide a wide range of operational data, the pushing of axle loads towards 40 tonnes, and work being done to improve welding technology.

But such innovation is not confined to the Pilbara, or to permanent way. There are other notable developments in several other parts of the industry.

Close to home, ARTC is progressing the development of its Advanced Train Management System (ATMS). This effectively transfers wayside signalling onto the train, controlled from a central location. A train's location is monitored continuously and accurately, doing away with the need to provide track circuits for train detection.

In addition, the concept of progressing a train through fixed block sections no longer applies, providing much greater flexibility in train operation. Such concepts have become possible through the availability of enhanced and reliable communications systems.

Europe has always been at the forefront of developments in light rail, trams, and related forms of urban transport.

A new technical advance is light rail and/or tram systems which do away with the need for overhead catenary, improving the aesthetics of the transport corridor. This can be achieved in two ways.

The first method used a conductor embedded in the road surface. But instead of being continually energised, the power supply is activated only when the presence of a rail vehicle is detected, so that there is no electrical safety risk.

A variation on this concept is where the power is transferred to the vehicle by induction, as in an electric toothbrush.

The second way of avoiding overhead catenary is to fit the vehicle with storage batteries. This technology has been developed to a stage where a length of several kilometres can be traversed on battery power, such as through critical central-city areas.

These are just some examples of the way in which innovative technologies are supporting the growth of the rail industry.

But to meet the demands being placed on rail, we cannot afford to be complacent. Innovation and the development of technology is critical to the future success of the industry.

That is why RTSA's first objective is to "promote technological and management excellence in the railway industry".

Duncan McLeod

Rail Maintenance Developments in Heavy Haul – P. Mutton

The slides from this presentation can be seen on the following pages.

Heavy haul rail research: IRT

- BHP Billiton Iron Ore
  - Program commenced 1972 (Mt Newman Mining)
    - Address high rates of wheel and rail wear, rail corrugations encountered during initial haulage operations
  - Ongoing (continuous) program to support increased axle loads, haulage rates
- Rio Tinto (Hamersley Iron, Pilbara Iron)
  - Initial joint program with BHP (1970's-1980's)
  - New program established in 2006

Heavy haul vs the rest

What is the same?

- Conventional track designs
  - Ballasted track
  - Concrete sleepers
- Continuously-welded rail
  - 68kg/m & 141lb/yd
- 3-piece bogie designs
- High adhesion locomotives

What is different?

- Owned and operated by mining companies
  - Fully integrated below and above rail
- Higher axle loads
  - 35-40 tonnes
- Train configurations
  - 200-300 car consists
  - Head-end or distributed power
- Traffic density
  - ≥ 14 train schedule
- High cost of disruption to haulage operations

Heavy haul challenges

- Higher rates of component deterioration
  - Rail and wheel wear
  - Rolling contact fatigue damage
  - Rail defects, broken rails
  - Ballast deterioration
- Reduced track access for inspection and maintenance

Rails

- Rail performance influenced by:
  - Material characteristics
    - Composition
    - Mechanical properties
  - Rail deterioration
    - Wear
    - Rolling contact fatigue (RCF)
  - Rail maintenance (grinding)
    - Implementation of required profiles
    - Profile control during maintenance grinding
    - Metal removal rates, in particular that required to manage RCF damage

Rolling contact fatigue damage: Rails

- Control of RCF damage dictates grinding strategy for curved track
  - 8-10 MGT for high degree curves
  - 0.2 mm depth of metal removal
- Severity of RCF damage varies with:
  - Curve radius
  - Train speed/total train resistance
  - Worst locations
    - Sequence of reverse curves (2-3 degree)
    - Slow speed (20-30 km/h)

RCF damage: Rails

2.25 degree curve, down grade, HH rail, train speed 50-60km/h

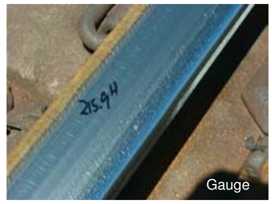
High rail

Low rail

Rail condition prior to grinding

RCF damage: Rails

2 degree curve, top of grade, HH rail, train speed 40-50km/h



High rail

Low rail

Rail condition prior to grinding

RCF damage: Rails

2.5 degree curve, up grade HH rail, train speed 20-30km/h

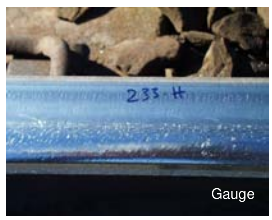
High rail

Low rail

Rail condition prior to grinding

RCF damage: Rails

3 degree reverse curve, up grade, LAHT rail, train speed 20-30km/h



High rail

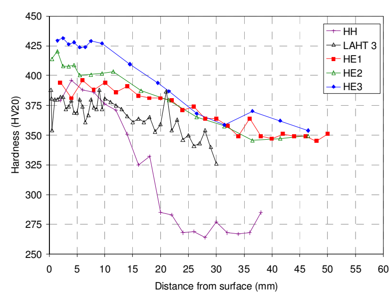
Low rail

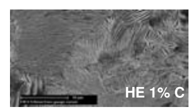
Rail condition prior to grinding

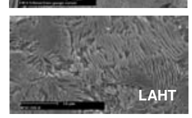
Rail material requirements

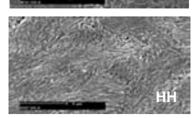
- For current operating conditions, ***minimum*** rail material requirements are equivalent to:
  - Head hardened rail (AS1085.1)
  - 350 LHT to EN13674-1
- ***Preferred minimum*** grade is low alloy in-line heat treated (LAHT) or equivalent:
  - High strength (AREMA)
  - 370LHT or above
- Minimum and preferred minimum rail grade categories are nominally eutectoid (0.7-0.8%) carbon, fully pearlitic microstructure
- Hypereutectoid (0.9-1.0% C) heat treated grades offer potential for improved rail performance over eutectoid grades

Hardness/microstructure in high strength rail steels









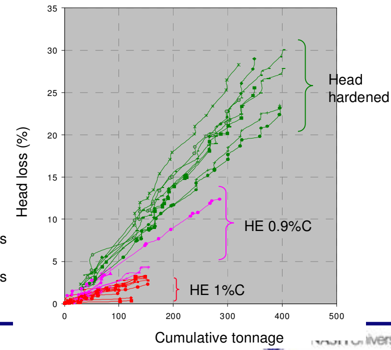
Rail performance: HE grades

- RCF behaviour influenced by track location:
  - Increased tendency for surface cracking and spalling in high traction curves
  - Surface damage exacerbated by lower wear rates
  - Poor surface condition results in "untestable" rail condition and compromises rail inspection
  - Revised grinding strategy implemented to manage surface condition
- Grinding cycle can be extended in less-demanding locations
  - Low traction curves
  - Tangent track

High Creep/Traction   Low Creep/Traction

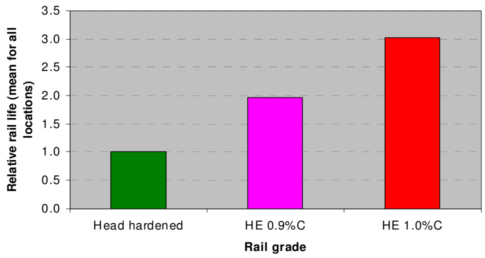
Rail performance data

- Rail performance monitored in conjunction with rail grinding program
  - Metal loss due to wear plus rail grinding
  - Rail grinding typically represents:
    - 85% of total loss in tangent track
    - 60% of total loss in curves



Rail performance data

- Estimated rail life includes metal loss due to wear and rail grinding



Track condition monitoring

- Instrumented ore car (IOC)
  - Permanently instrumented vehicles operating on a day-to-day to measure vehicle-track interaction
    - 3 vehicles operating at BHP Billiton Iron Ore
    - 1 unit in operation at Pilbara Iron, additional units proposed.
  - Equipped to monitor a variety of parameters tailored to the requirements of the rail operator
  - Fully automated system provides as means of monitoring:
    - Track condition throughout the network
    - Vehicle response
    - Longitudinal train behaviour

Instrumented ore cars

- IOC's operate as part of the fleet
  - Same speed profile, axle load (empty/loaded), suspension characteristics, wheel base, etc.
    - Use of several vehicles covers different bogies designs within the fleet
  - Provide and alternative to track recording cars and other means used to assess track condition
    - Measured data reflects response of major vehicle type
    - Continuous monitoring, frequent reporting

Instrumented ore cars

Original unit (BHPB-IO)

(Comeng body design)

Newer unit (BHPB-IO)

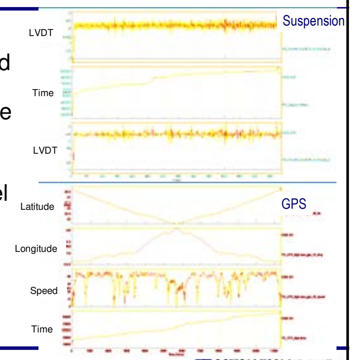
(GoLynx body design)

IOC's: Typical instrumentation

- Spring nest deflection (both bogies)
  - Suspension travel used to assess track geometry
- Vertical accelerations above wheelsets
  - Leading and trailing wheelsets only
  - Rail running surface condition
- Longitudinal force at fixed coupler
- Position (GPS)
- Brake pipe pressure
- Additional sensors on as-required basis
  - Strain gauges (car body, draft gear, etc)
  - Bearing temperatures

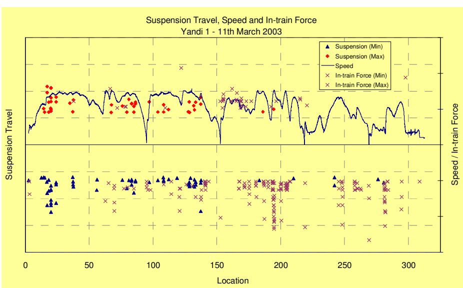
Vehicle response

- Spring nest movement and GPS data collected in raw form as a function of elapsed time
- Data is reduced and reported to track maintenance personnel

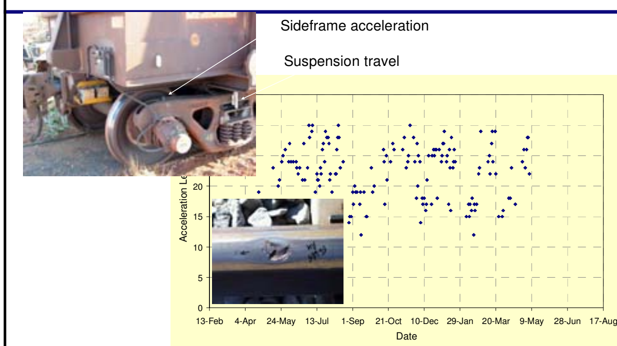


IOC data reporting

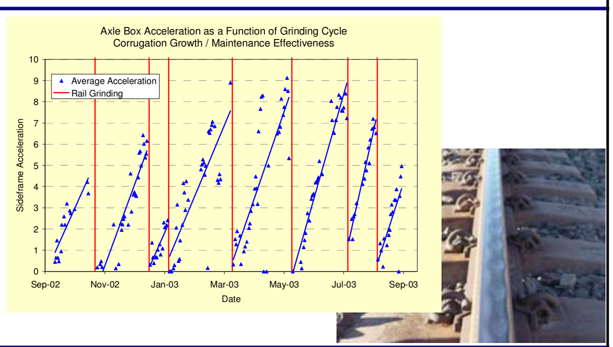
- Measured suspension travel and in-train force



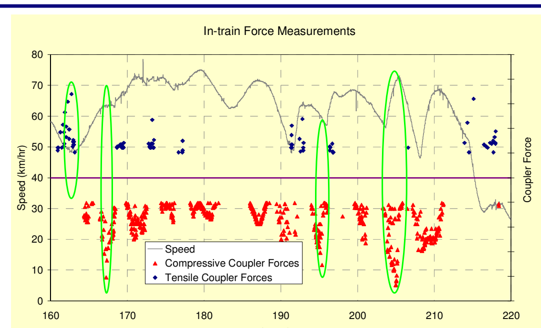
Monitoring impact loading at welds



Trending IOC data: Rail corrugations

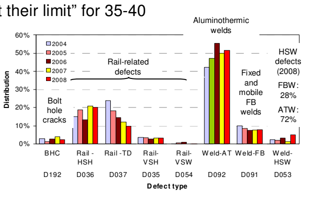


Measurement of In-train Forces



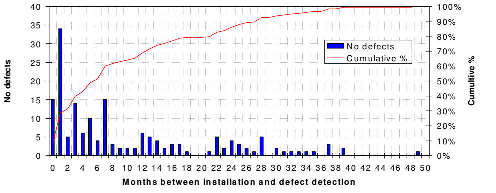
Rail welds

- Flashbutt and aluminothermic processes
  - Fixed and mobile flashbutt plant
  - Boutet PLK (Railtech) aluminothermic welds
- With improvements in rail materials (quality, mechanical properties), rail welds dominate rail defect and broken rail statistics
  - Aluminothermic welds are “at their limit” for 35-40 tonne axle load operations



Ultrasonic defects in AT welds

- Defect statistics indicate high proportion in newly-installed welds:
  - ~50% within 12 months of installation
  - Emphasis on competency of personnel and welding equipment, procedures



Fatigue failure modes: Head-web radius

- Initiated at weld defects in head-web radius
- Increased failure risk in welds with dissimilar height rails
  - Failure occurs in smaller rail
- Defect initiation
  - Gap between mould and rail surface
  - Defect formed due to possible reaction between stemming paste and liquid metal

Fatigue failure modes: Upper fatigue

- Fatigue cracking, initiated at top of foot, edge of weld collar
- Most common failure mode
  - Generally associated with IRJ’s & switches (poor support)
- Contributing factors
  - Dissimilar rail height
    - Failure on larger rail side in most, but not all cases
  - Gap between mould and rail surface
    - Poor detail on upper surface of foot at fusion boundary
  - Poor rail support conditions
    - Unsupported sleepers/”pumping” welds
      - Higher bending stresses in rail foot

Horizontal split web failures

- Initiated at hot tears or shrinkage cracks at outer edge of weld collar
- Not a common failure mode in Boutet process
- Typically overload failure
  - No evidence of fatigue crack growth
- Contributing factors
  - Impact loading
  - Broad contact band
    - Increased eccentric loading

Strategies for improving weld performance

- Minimise use of AT welds wherever possible
  - Mobile FBW used for rerail, defect replacement
- Ensure AT process is “best available” and all welds installed correctly
  - Understand the relationship between the loading conditions and weld behaviour, and use this to assess alternative processes
- Qualification of all new welds
- Welder qualification and monitoring

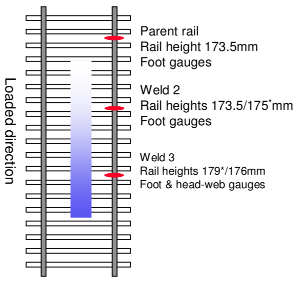
Inspection procedures for AT welds

- Radiographic inspection
  - Implemented for identification and reporting of weld defects
    - More stringent rejection criteria for centreline shrinkage and inclusions
    - Ongoing assessment of inspection data identifies poor welding procedures
- Ultrasonic inspection
  - Improved testing strategy to detect defect types that are characteristic of AT process in use.

Weld instrumentation

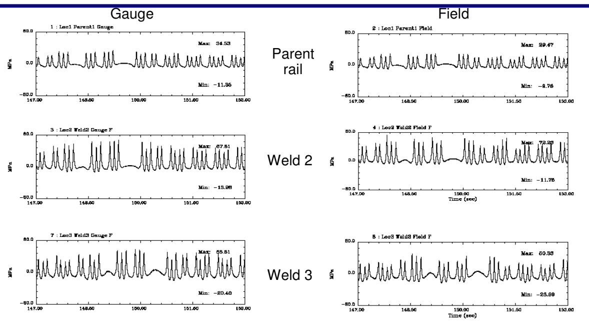
- Aim:
  - Measurement of stresses at critical locations under service loading
    - Head-web radius (adjacent to edge of weld collar)
    - Top of rail foot (adjacent to edge of collar, 50mm from toe)
    - For welds with dissimilar heights, larger rail side
  - Identify influence of track condition and vehicle-track interaction on weld response

Test site

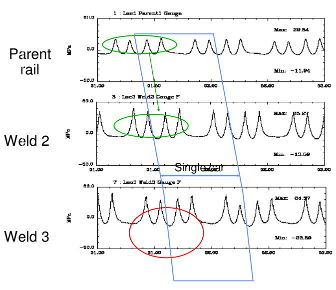


* Side of weld instrumented

Stress history under loaded traffic: Upper foot

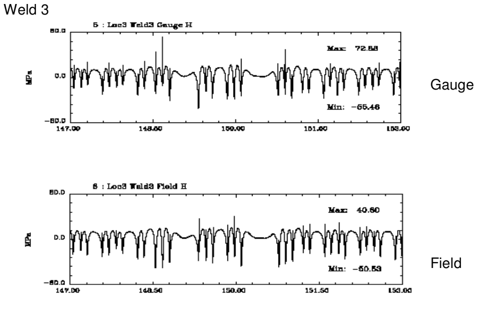


Stress history details: upper foot (gauge side)



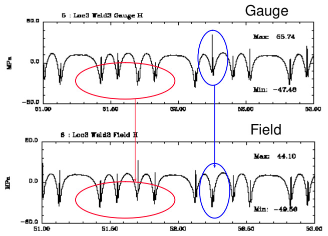
- Foot stresses
  - Increase in peak stress levels for normal welds relative to parent rail

Stress history under loaded traffic: Head web



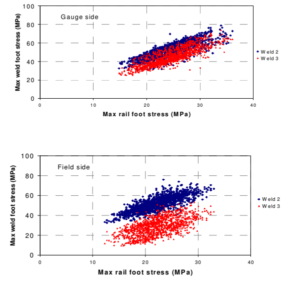
Stress history detail: Head-web (gauge)

Weld 3



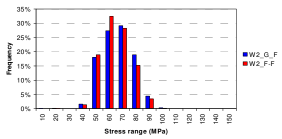
- Head-web stresses
  - More complex response due to
    - Longitudinal bending (compressive stress)
    - Localised wheel-rail contact (tensile stress); magnitude dependent on wheel lateral position

Upper foot: Weld vs parent rail

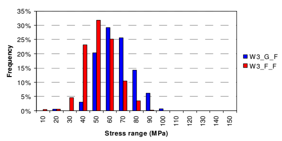


- Upper foot stresses
  - Multiplication factors (weld/parent rail)
    - 2-2.5 for good welds
    - Increases for poorly-supported welds

Upper foot: Stress range



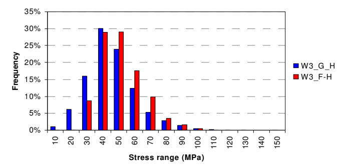
Weld 2



Weld 3

- Peak stress ranges
  - Up to 100MPa in well-supported welds
  - Higher in poorly-supported welds with dissimilar rail heights

Head-web radius: Stress range



- Peak stress ranges
  - Up to 100MPa in well-supported welds
  - Higher in poorly-supported welds with dissimilar rail heights

Weld instrumentation: Summary

- Foot stresses (longitudinal at edge of collar)
  - Peak stress ranges
    - Up to 100MPa (tension) in well-supported welds
    - Up to 50% higher in poorly-supported welds with dissimilar rail heights
- Head-web radius stresses (longitudinal at edge of collar)
  - More complex stress response
    - Compressive due to longitudinal bending with tensile spike associated with localised wheel-rail contact
    - Double number of fatigue cycles compared with upper foot
  - Peak stress ranges
    - Up to 100MPa in well-supported welds
    - Up to 40% higher in poorly-supported welds with dissimilar rail heights

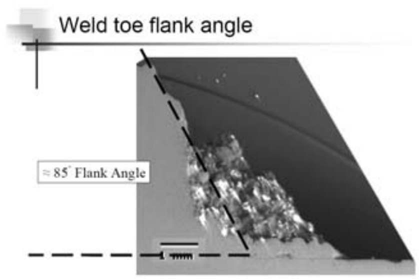
Assessment of alternative AT processes

- Comparison of Boutet PLK and Thermit SKV-E aluminothermic welds

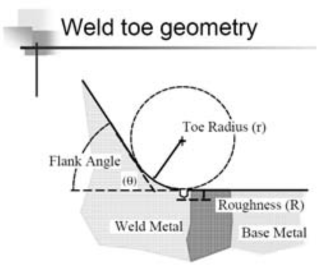
General comments on weld collar designs

- Detail at edge of collar, particularly at top of rail foot, and head-web radius, influences stress concentration under in-track loading conditions (longitudinal stresses)
- Extent of weld metal penetration beyond weld collar also influences fatigue behaviour under longitudinal bending
- Vertical stresses at weld collar (centreline) strongly dependent on collar shape

Upper foot region: edge of collar



Upper foot region: edge of collar



- Fatigue severity increased by:
  - larger flank angles
  - smaller toe radii
- Fatigue severity reduced by:
  - reduced surface roughness

$$Fatigue\ Severity = \left(1+0.27\tan\theta^{0.25}\sqrt{\frac{t}{r}}\right)\left(1+0.1054S_u\sqrt{R}\right)-1$$

Other considerations

- Is the AT process design capable of producing a weld with acceptable performance characteristics when welds are made according to recommended procedures?
  - Sound welds (no shrinkage defects, large inclusions, hot tears, etc)
  - Acceptable residual stress levels and stress levels under service loading conditions
  - Hardness distribution adequate to minimise weld batter
- Does the process design enable good quality welds to be produced consistently under in-track conditions?
  - Ease of correctly fitting moulds, particularly for worn/dissimilar height rails
  - Tolerance to minor variations in weld gap, preheat conditions
- Are in-track welds well supported?
  - "pumping" welds can increase bending stresses in critical locations