Update on High-Strength Rail Steels

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Content of this Presentation

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Measures Against Rail Damage

Type of Damage	Measure
Wear	harder rail steel lubrication
Corrugations	harder rail steel improve track construction
Head-Checks	harder rail steel grinding
Spalling	grinding machining
Squat	preventive grinding
Internal defects	ultra-clean rail steel

R & D Targets of Rail Steel Development

- The longest possible lifetime – conserve the rail profile by
  - high wear resistance
  - little material removal by grinding
  - consistent rail-wheel-contact

- The lowest requirement for maintenance – reduce costs
  - increase rolling contact fatigue (RCF) resistance – at initiation stage
  - reduce crack growth speed – when RCF cracks are present

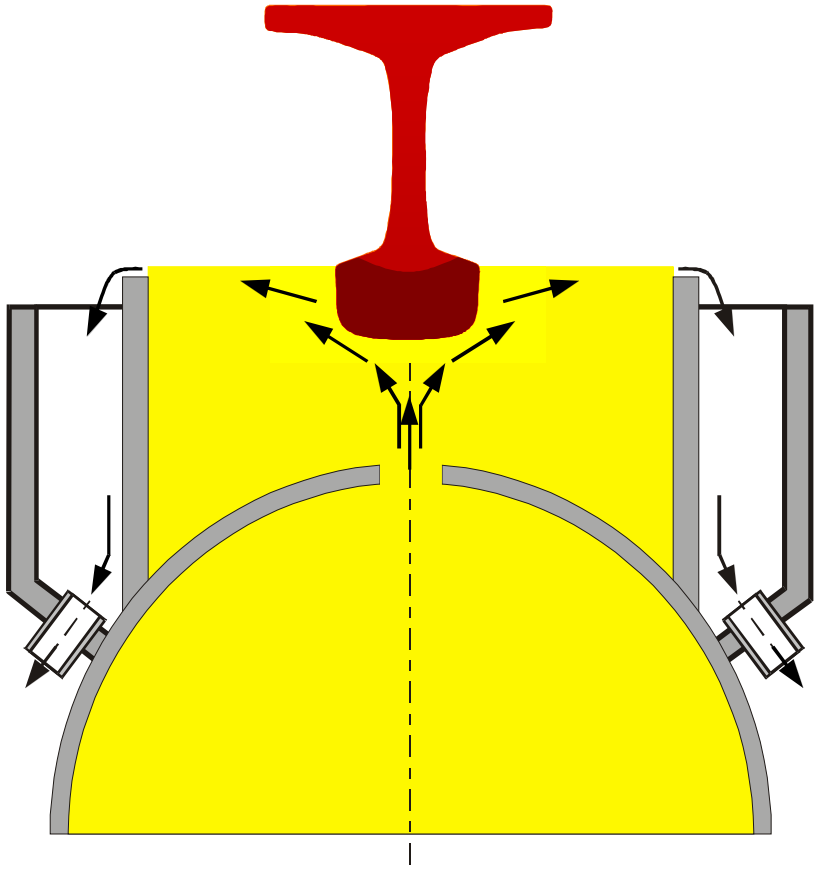
- The highest possible reliability – reduce premature failures
  - ultra-clean rail steels – avoid ultrasonic findings
  - take care for reliable welded joints

Standard Carbon Rail Steels – EN13674

	C [%]	Si [%]	Mn [%]	Cr [%]	R_m min. [N/mm²]
R200	0,40–0,60	0,15–0,58	0,70–1,20		680
R220	0,50–0,60	0,20–0,60	1,00–1,25	max. 0,15	770
R260	0,62-0,80	0,15-0,58	0,70-1,20	max. 0,15	880
R260Mn	0,55-0,75	0,15-0,60	1,30-1,70	max. 0,15	880
R320Cr	0,60-0,80	0,50-1,10	0,80-1,20	0,80-1,20	1080

Alloying is limited by toughness and welding requirements

HSH® – the Head Hardening Process



- refinement of the pearlitic microstructure
- all types of rail profile:
  - vignole rails
  - tongue rails
  - grooved rails
  - crane rails
- highest productivity

- more than 10 steel grades between 290-440 BHN hardness

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High Strength Head Hardened Rail Steels

	C [%]	Si [%]	Mn [%]	Cr [%]	R_m min. [N/mm²]	improvement to R260
R350HT	0,72-0,80	0,15-0,58	0,70-1,20	max. 0,15	1175	300 %
R350LHT	0,72-0,80	0,15-0,58	0,70-1,20	max. 0,30	1175	300 %
370LHT	0,70-0,82	0,40-1,00	0,70-1,10	0,40-0,70	1280	> 600 %
400UHC	0,90-1,00	0,20-0,40	1,20-1,30	0,20-0,30	1280	> 800%

high strength and hardness by combination
of the in-line heat treatment with smart alloying

Bainitic Rail Steels for Mainline Tracks

type	features	manufacture	properties and application
Lower Bainite	§ 0,80 % C § 0,50 % Cr § 0,20 % Ni § 0,15 % Mo & V	§ voestalpine § in-line heat-treated § Dobain 430	§ wear resistance like HSH® § RCF resistance like 370LHT & 400UHC
Carbide-Free	§ 0,20 – 0,30 % C § 1,50 % Si § 0,50 % Cr § 0,15 % Mo & V	§ Corus Hayange § naturally cooled § B320 and B360	§ wear resistance less than R260 § good RCF resistance
	§ 0,40 % C § 1,10 % Si § 1,10 % Cr § 0,10 % V § 0,70 % Mo (!)	§ TSTG § naturally cooled § R_m 1300 MPa	§ better wear resistance § good RCF resistance
Naturally Cooled and Tempered		§ TSTG § naturally cooled and tempered § TB1400	§ better wear resistance § good RCF resistance § no ultra-long rails due to tempering
	§ 0,35 % C § 2,50 % Cr § 0,30 % Mo § 0,10 % V	§ Neue Maxhütte (†) § naturally cooled and tempered § R_m 1400 MPa (420 BHN)	§ best in German tests § high wear resistance and no RCF § no ultra-long rails due to tempering
Multi-Phase	§ 0,55 % C § 0,50 % Cr	§ voestalpine § in-line heat treated	§ new concept § adjusts the best microstructure by in-line heat treatment § hardness adjustable in a wide range

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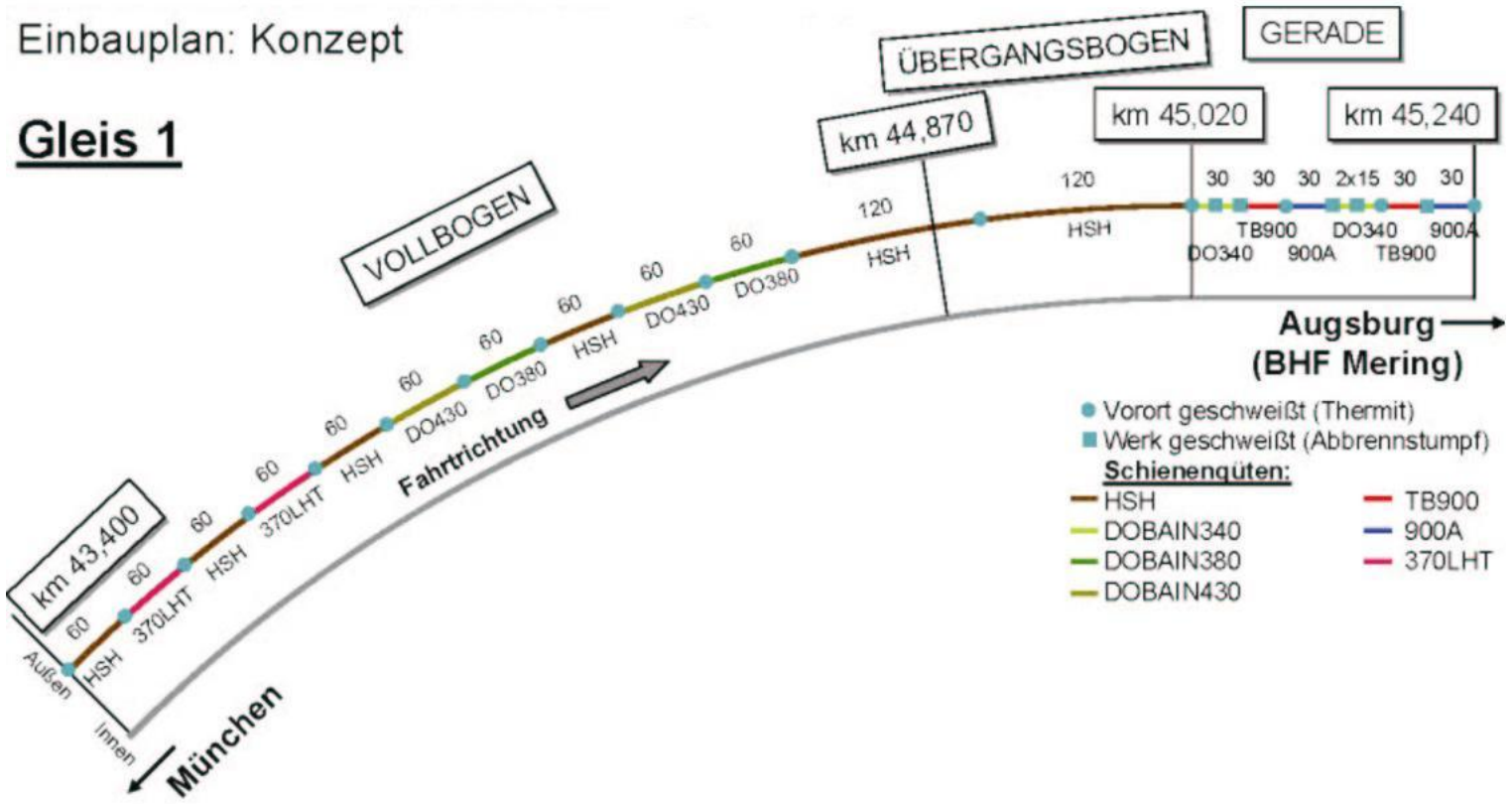
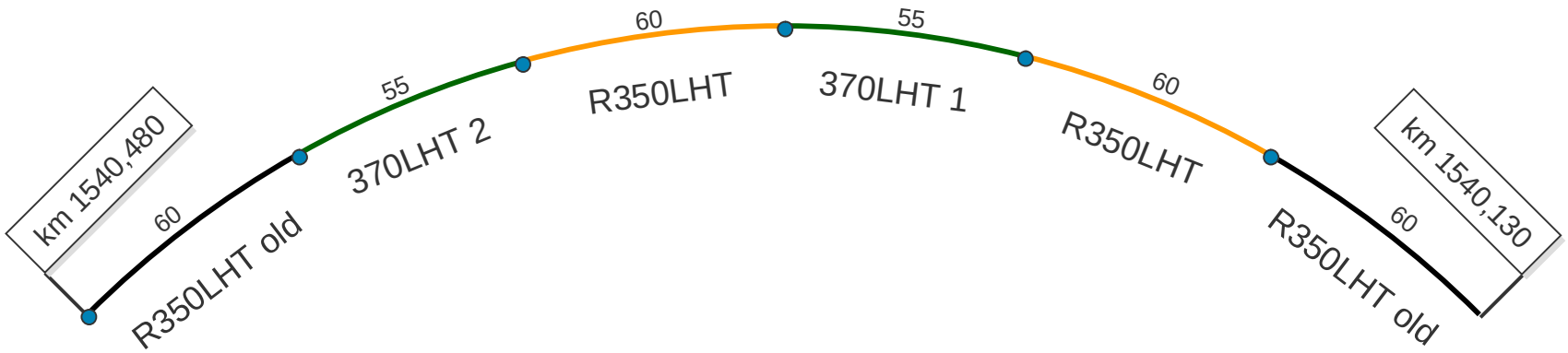
Track Testing – Typical Layout at DB AG



Malmbanan 370LHT Track Test Katterjåck



Rijksgränsen **Katterjåck**

- 4 new rail pieces installed end of July 2008
- with aluminothermic welds
- ground to match the profile of the old R350LHT rails end of August 2008
- ground to MB1 profile

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Wear and Corrugation Measurements

- Crossectional profiles: Miniprof
- Longitudinal profile: RM1200

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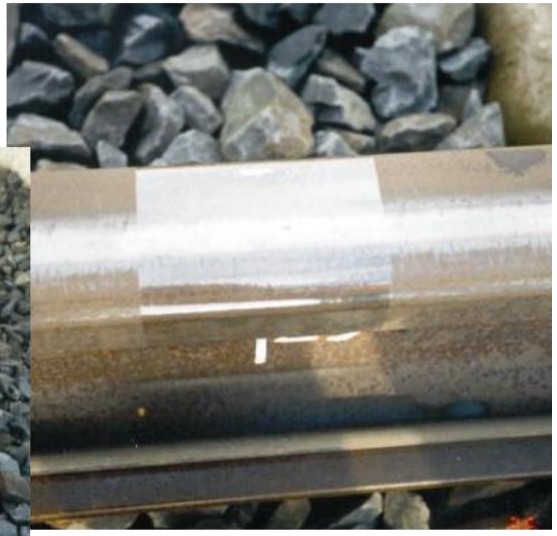
RCF – Crack Characterization



- Magnetic particle inspection
- In-Track Eddy current testing
- Metallography of cut samples

Example – DB AG Hannover

- track Hannover-Celle
- mainly passenger trains (P230)
- traffic: two tracks
- load: 60.000 t/day
- axle load: up to 22,5 t
- speed: max. 160 km/h
- radius: 534 & 614 m
- cant [mm]: 90 mm
- inclination: 0 ‰

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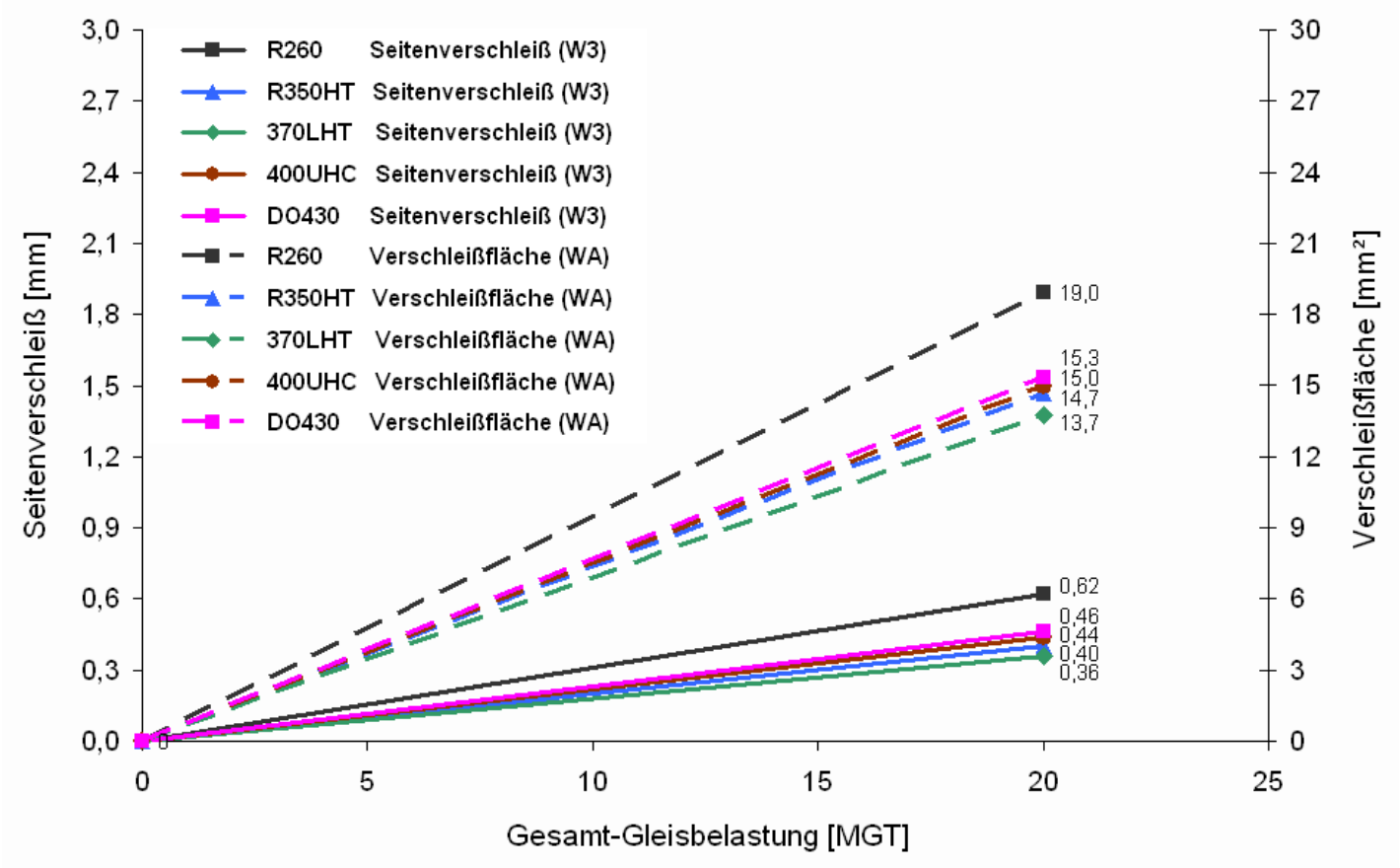
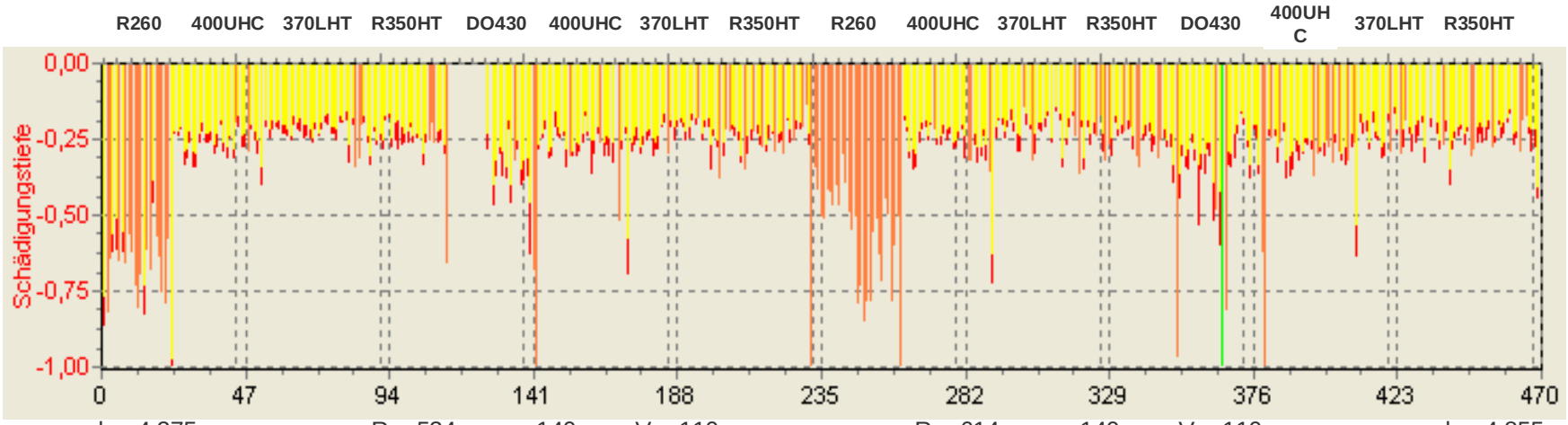
Wear Results after One Year (20 Mio to)



Head-Check Depth after Two Years (42 Mio to)



- R260 shows greatest depth of the head-checks
- all head-hardened rails 370LHT, 400UHC, Dobain430 show about the same depth
- different grinding requirements – 50 % less needed

Utilization of Head Hardened Rail Steels

- Hard rail together with preventive grinding supports for
  - largest life cycle
  - lowest total costs

- DB AG: R350HT rails for curves below 1.500 m radius
- Prorail: R370LHT rails for curves below 3.000 m radius
- ÖBB: R350HT rails for curves below 3.000 m radius
- JBV: 370LHT for curves in the Ofotbanan
- BV: tests with 370LHT in the Malmbanan

- 370LHT and 400UHC will be integrated to EN13674-1

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Welding Methods for Rails

- Butt Welding – Rail Joints
  - flash butt welding – direct electric heating
  - induction welding – indirect electric heating
  - gas pressure welding – gas flame heating
  - stationary or mobile
- Electrode Arc Welding – Flux Core
  - rail joints – only in urban railway systems
  - repairs of localized surface defects
  - reprofiling of worn areas of grooved tramway rails
- Aluminothermic Welding – Rail Joints and Contacts
  - $2Al + Fe_2O_3 \rightarrow Al_2O_3 + 2Fe + \Delta E$
  - “field weld” – process, kit and welder

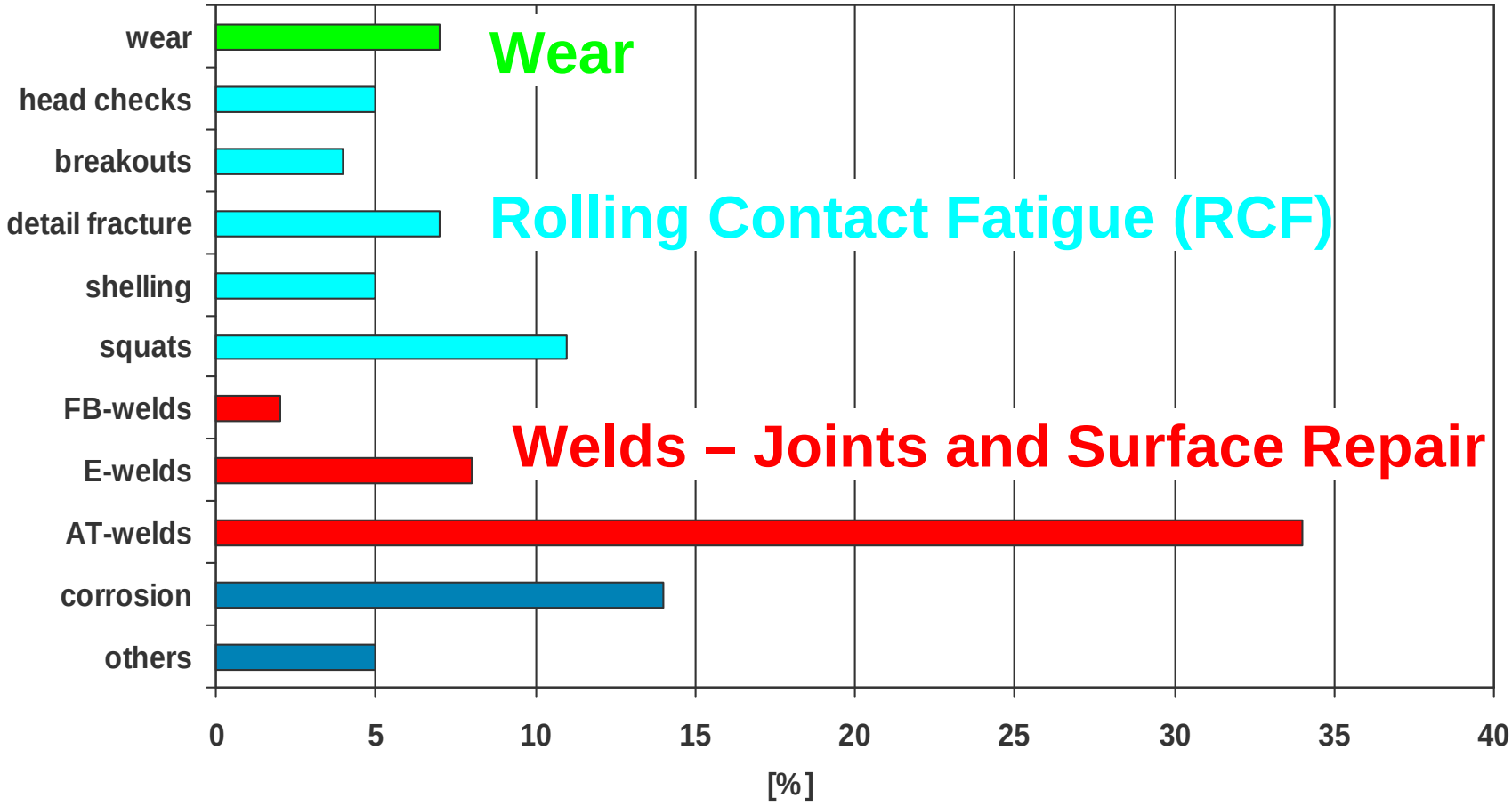
Quality Assurance:

automated process

manual or semi-automated process

manual process

Rail Failure Statistics – Example from Europe



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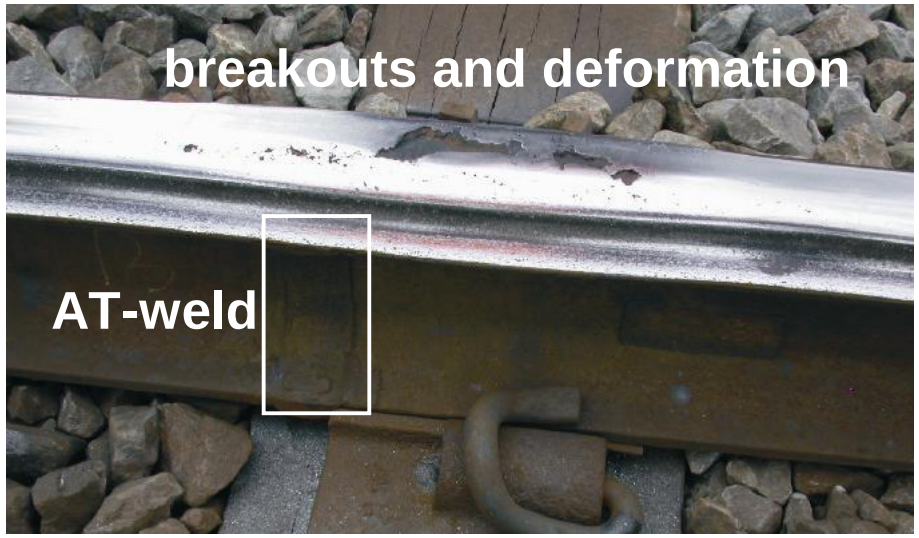
Weld Failures Limit the Track Reliability



Bad Geometry – Excessive Dynamic Forces

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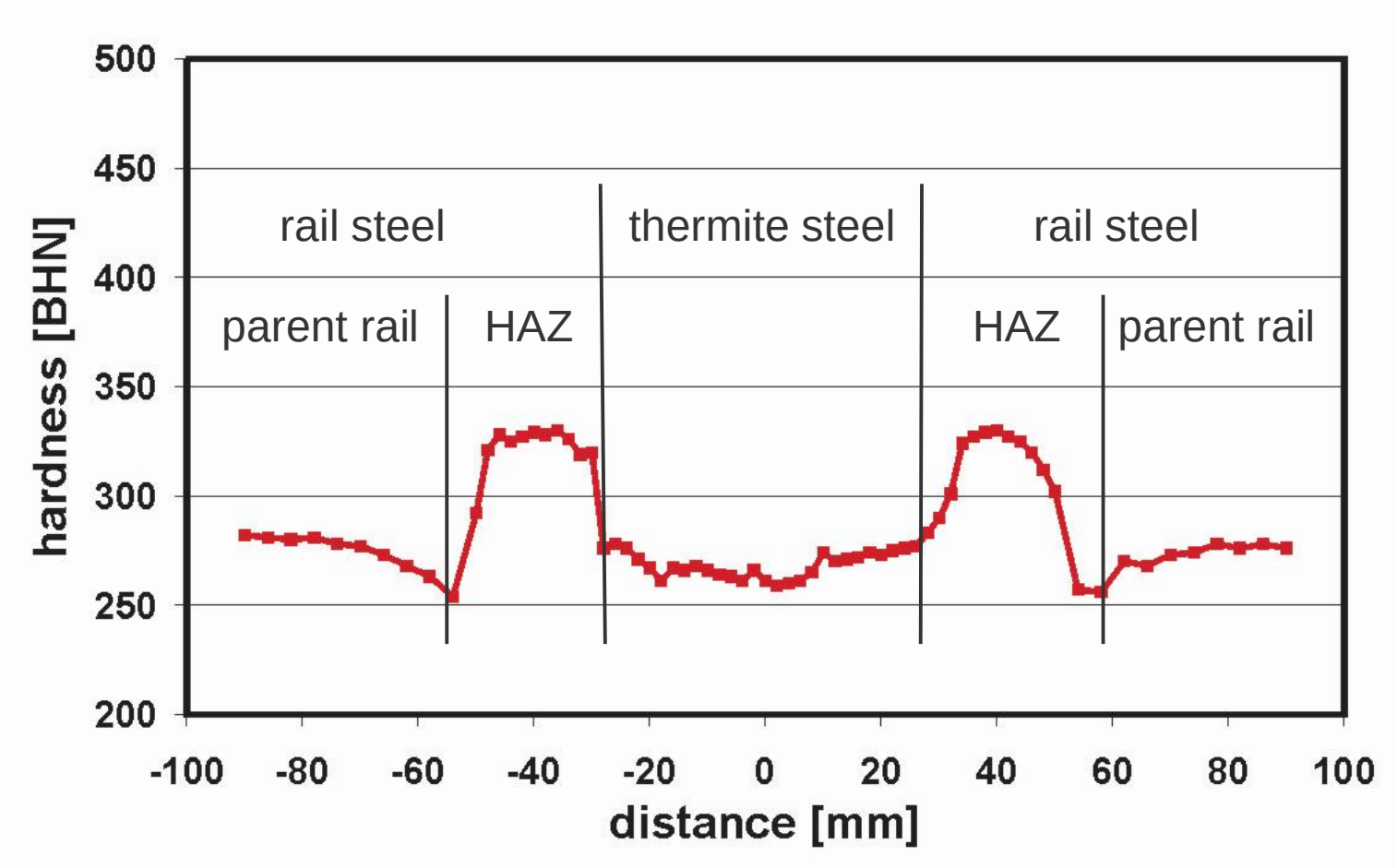
Hardness Traces along an R260AT-Weld



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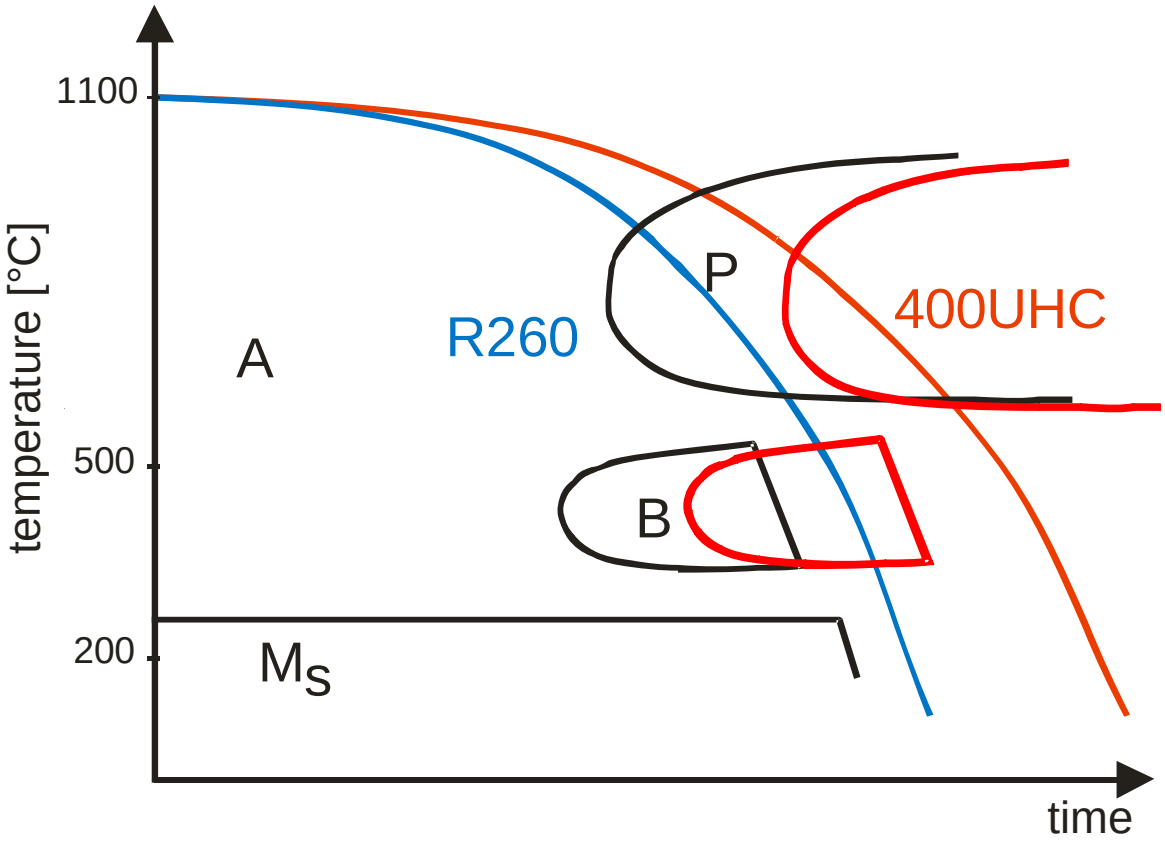
Welding of High-Strength Rail Steels



- alloying retards transformations
- reduce the cooling speed when welding to keep the microstructure pearlitic

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Steps in Development of High-Strength Welds

- Flashbutt Welds
  - Increase the heat input – add preheating pulses
  - Reduce the cooling speed – add post-heating pulses
  - Reduce the cooling speed – use insulating coats
- Deposit Welding
  - Evaluate appropriate preheating temperature → ≥ 400 °C
- Aluminothermic Welds
  - Increase the hardness of the portions – add Cr, V
  - Increase the heat input – longer preheating and/or larger portion
  - Reduce the cooling speed – use insulating coats

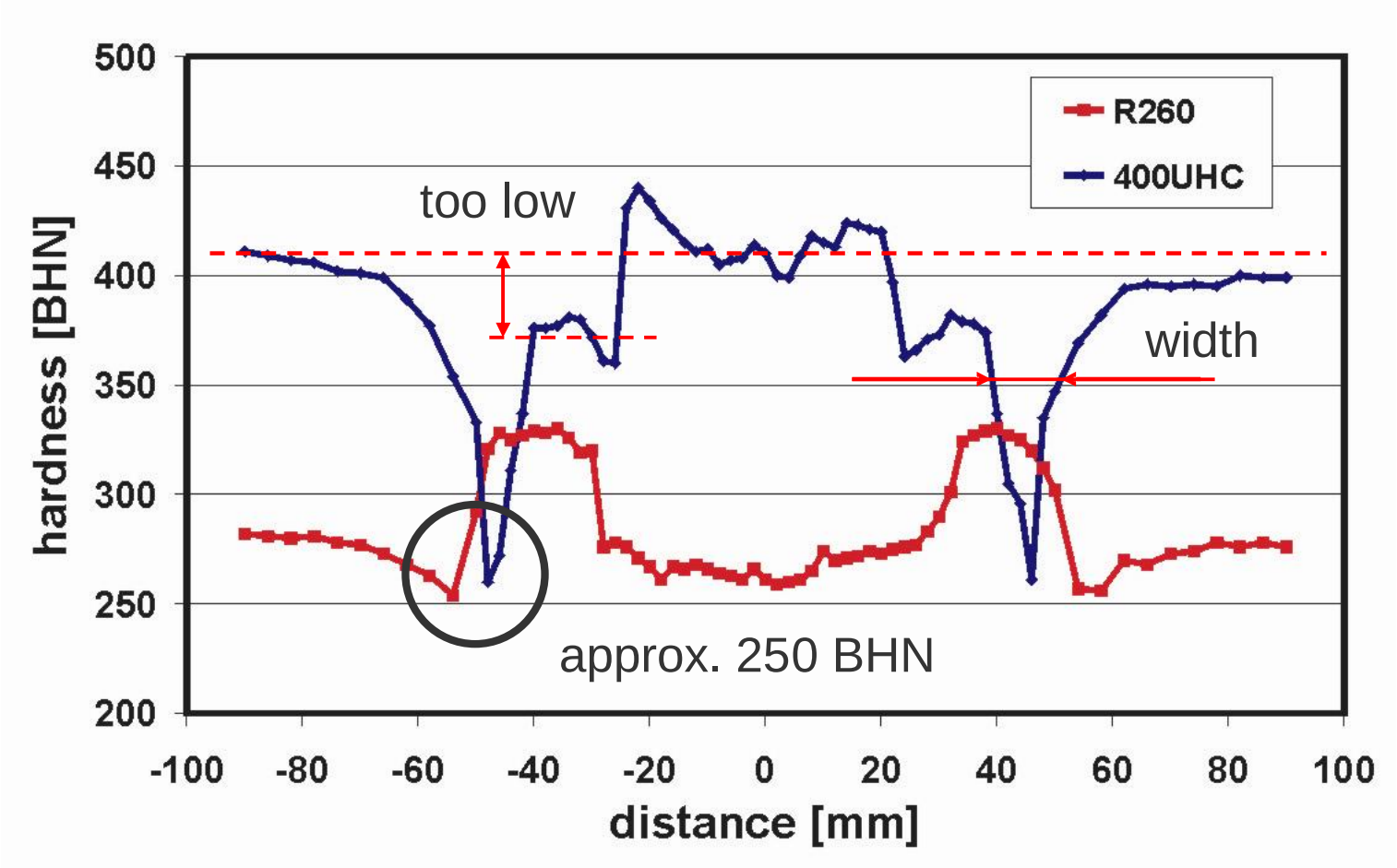
Keep

It

Stupid

Simple

Hardness Traces of a 400UHC AT-Weld



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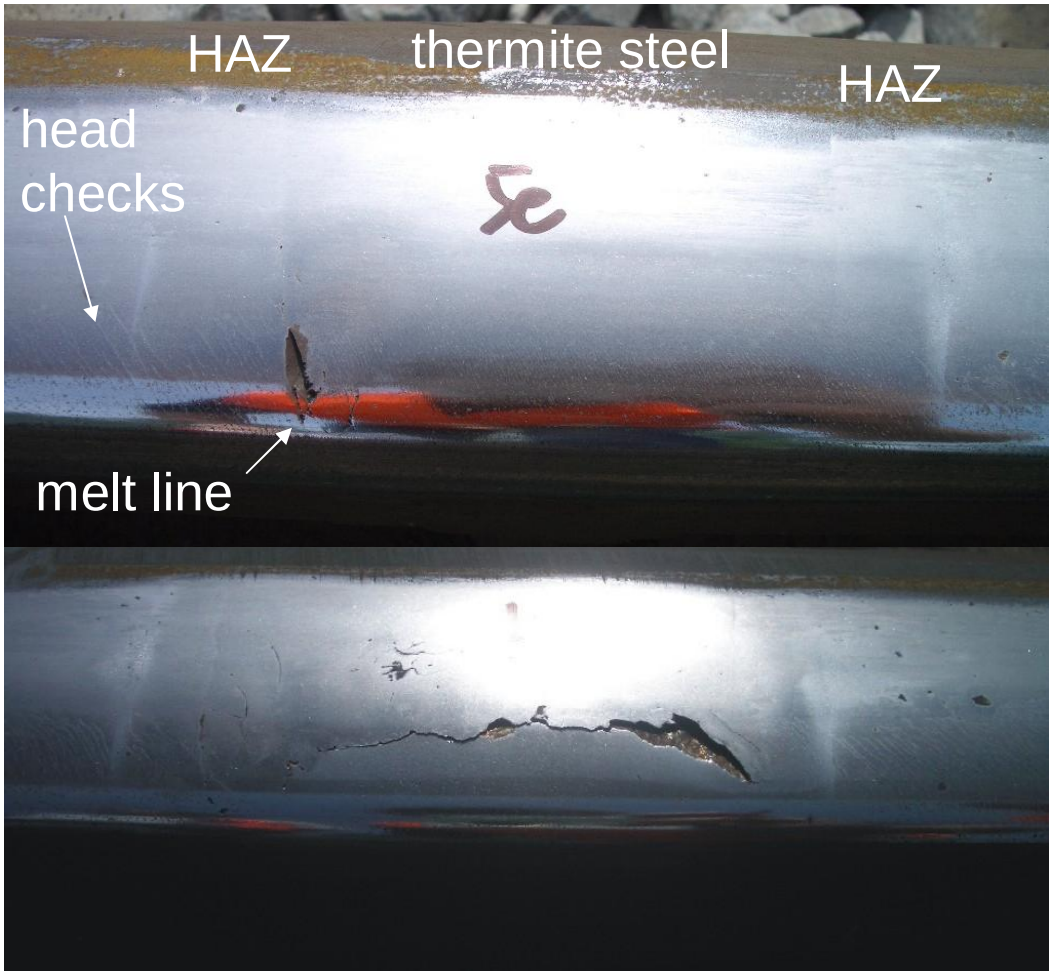
Performance of High-Strength AT-Welds



- acceptable battering
- Head-Checks along the gauge corner correspond to the hardness
- small breakout at the fusion line due to thin martensite layer

- massive surface cracking
- large breakout expected
- to be replaced

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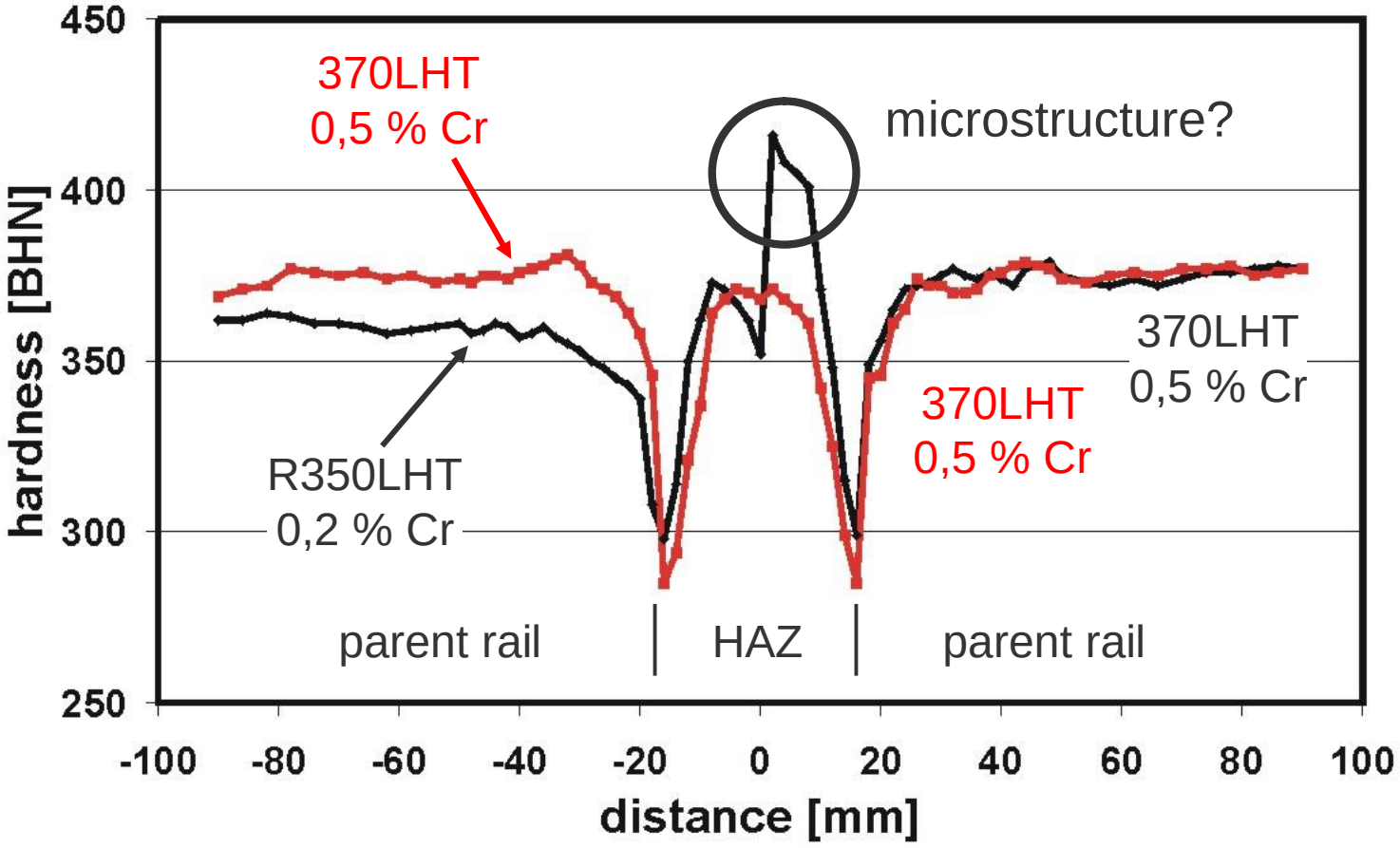
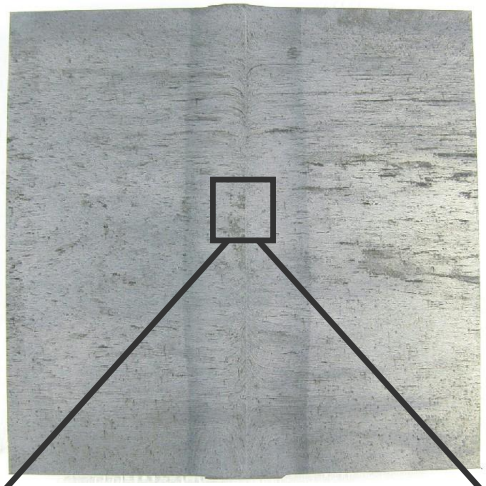
Hardness Traces of 370UHC Flash-Butt Welds

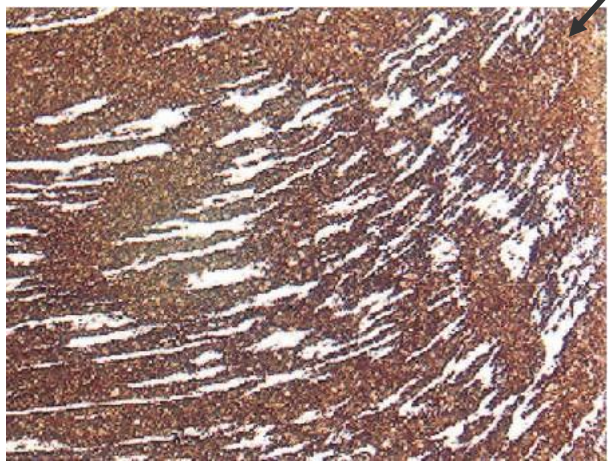


Flash-Butt Welding of Bainitic Rail Steels

microstructure in the web

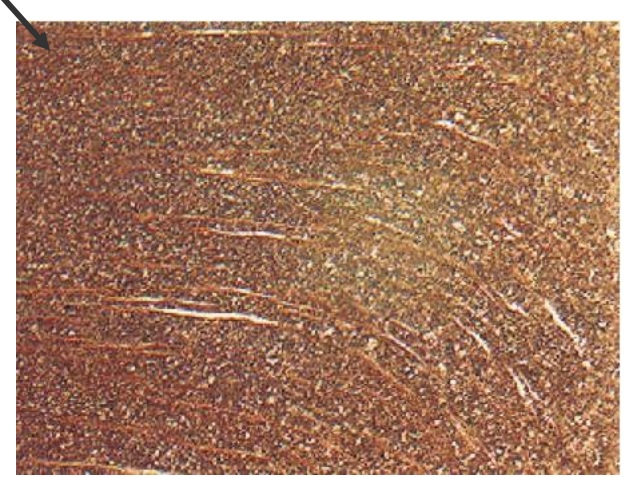


DOBAIN430 with
R350HT settings:
30% martensite



+ preheats
+ postheats
+ insulation

DOBAIN430 with
optimized procedure:
1,8% Martensit



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Performance of Bainitic Flash-Butt Joints

- DOBAIN 430
- plant flash-butt welding
- total seven years of service
- approx. 135 Mio to

Repair Welding of 370LHT Rail Steel

- Repair of localized defects
  - squats
  - breakouts
  - damage
- Reprofiling of worn areas
  - Switchblades

- Cooperation with local manufacturers
- Target:
  find the min. preheating temperature

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Summary

- High-strength rail steels offer:
  - the longest possible service lifetime
  - the lowest maintenance requirements and costs
- Rails are “non-weldable steels” by definition
- Welding process and material must be optimized for new metallurgies
  - proper time-temperature regime
  - welding consumables must be adjusted to hardness
- **K**eep **I**t **S**tupid **S**imple:
  - practical process
  - high failure tolerance
  - all welding methods are strongly influenced by manpower

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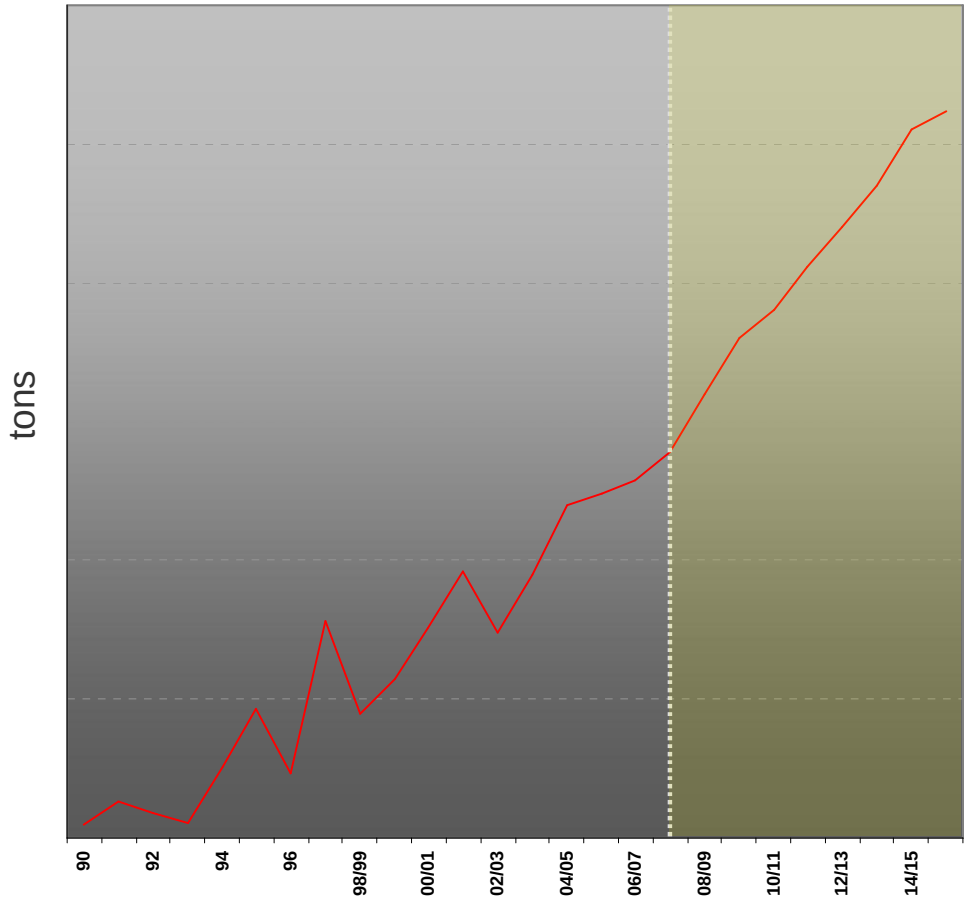
High Strength Rail Steels – the Market Forecast



- Consecutive implementation of RAMS- and LCC-strategy
- Europe:
  substitution of standard carbon rails by HSH®
- Overseas:
  increase of market share in Heavy Haul
- Need for effective head hardening methods

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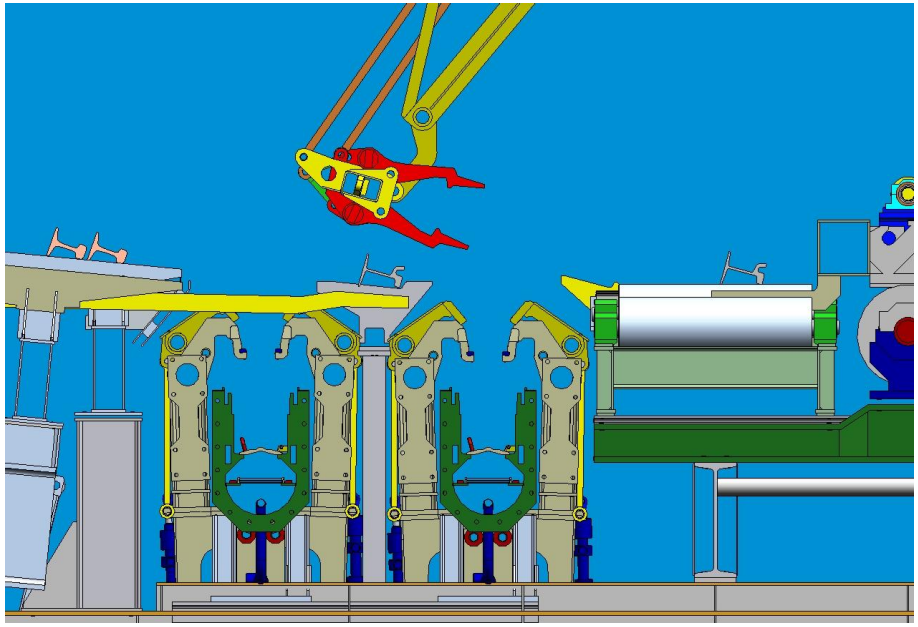
Twin Head Hardening Plant

- combined twin head plant
  for HSH® and DOBAIN® rails
- all profiles
  - Vignole
  - Tongue
  - Grooved
- for 120 m rail length
- capacity 600.000 to/year
- startup 07th Jan 2009



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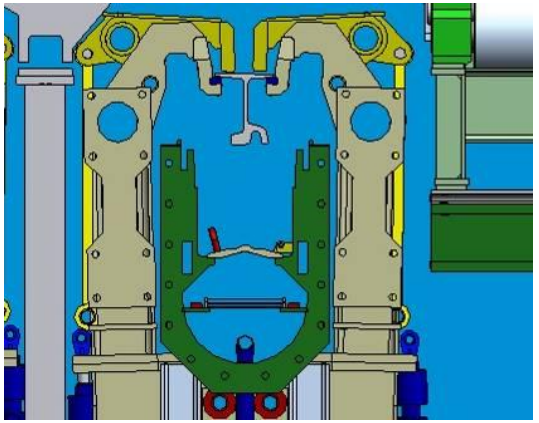
New Twin Heat Treatment Plant – Pilot Plant



- target: test of the manipulation system
- optimizing the plant design
- Being ready for a high productivity startup – There is no way back!

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Many Thanks to Our Welding Partners

- Thomas Cerncic
- Florianerbahn Service
- Goldschmidt-Thermit Group
- H.A. Schlatter AG
- ÖBB Infrastruktur Betrieb
- ÖBB Oberbauwerk Zeltweg
- Rail OK
- Railtech International
- Rolf Plötz Elektroschmelze
- VAE and VAEE Zeltweg

- And many thanks for your attention!