

Recent and Future Developments in Rail Steels

AG 60, Banverket, Borlänge

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Technical customer service

22. August 2003

voestalpine - Division **Bahnsysteme**

ONE STEP AHEAD

voestalpine
SCHIENEN GMBH

Why a Head-Hardened Rail?

Head Special Hardened Rails



Profile: AREA 136

Werte in HV30



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Head Special Hardened Rails



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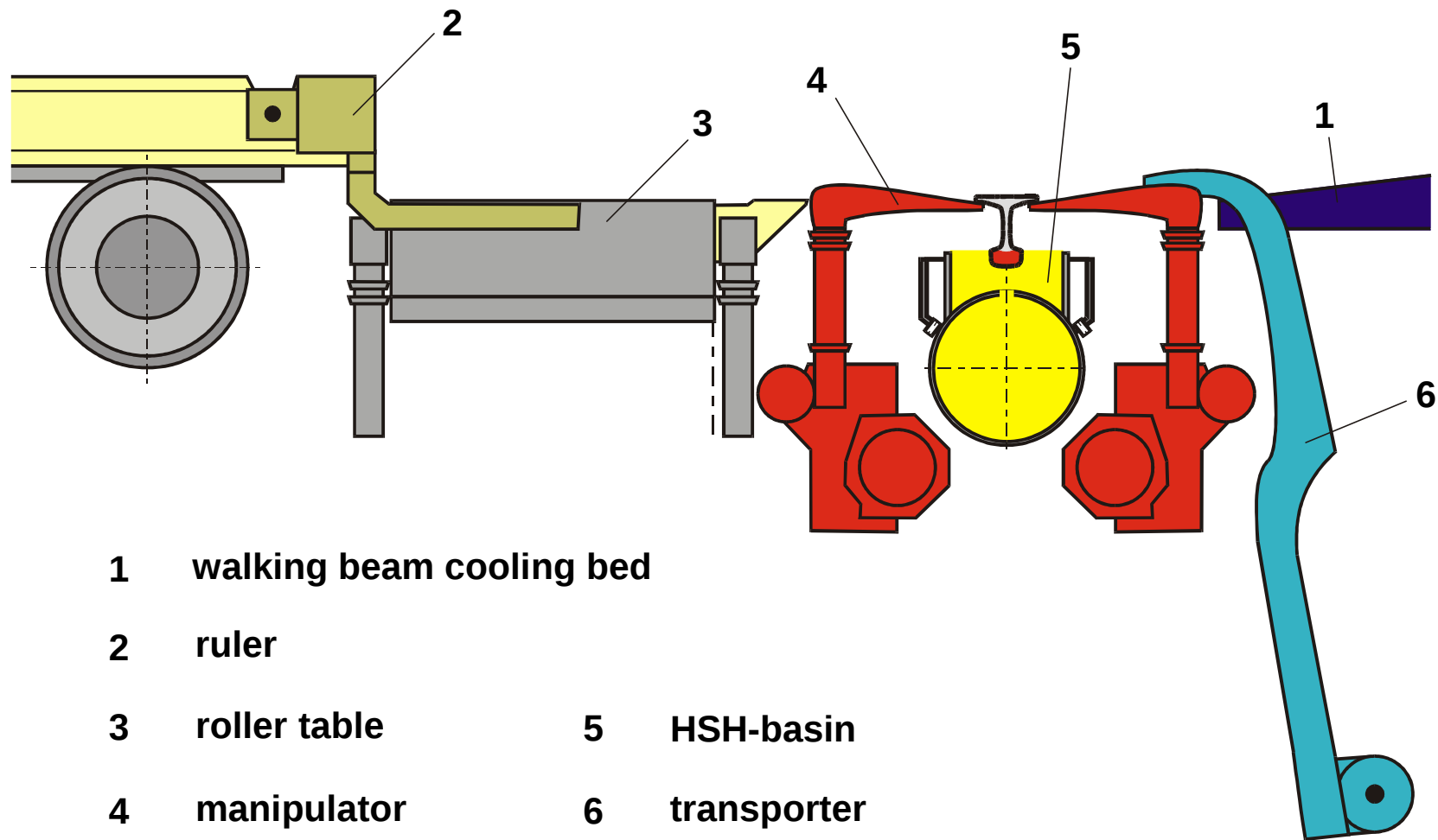
Cooling Bed - 125 m long



Head Special Hardened Rails

HSH – Scheme of the Process

Head Special Hardened Rails

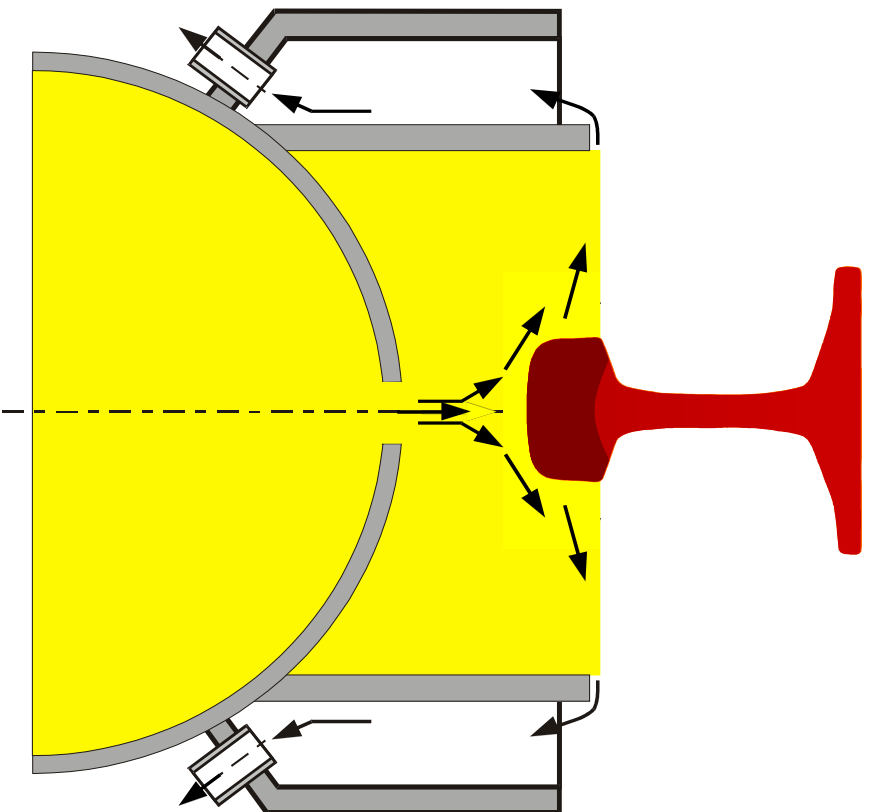


- | | | | |
|---|--------------------------|---|-------------|
| 1 | walking beam cooling bed | | |
| 2 | ruler | | |
| 3 | roller table | 5 | HSH-basin |
| 4 | manipulator | 6 | transporter |

Head Special Hardened Rails



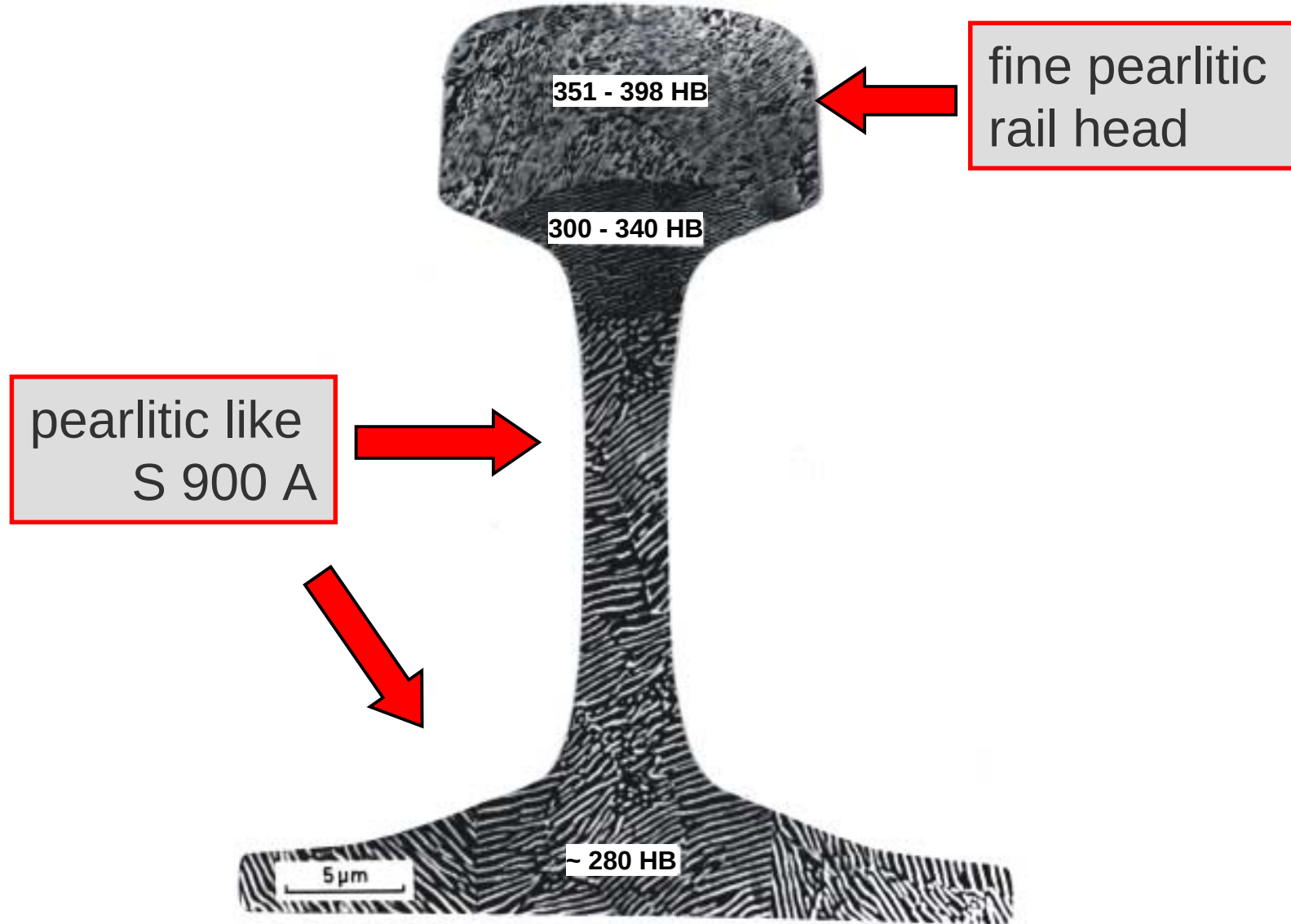
HSH – the Heat Treatment Process



Head Special Hardened Rails

HSH – Rails - Microstructure

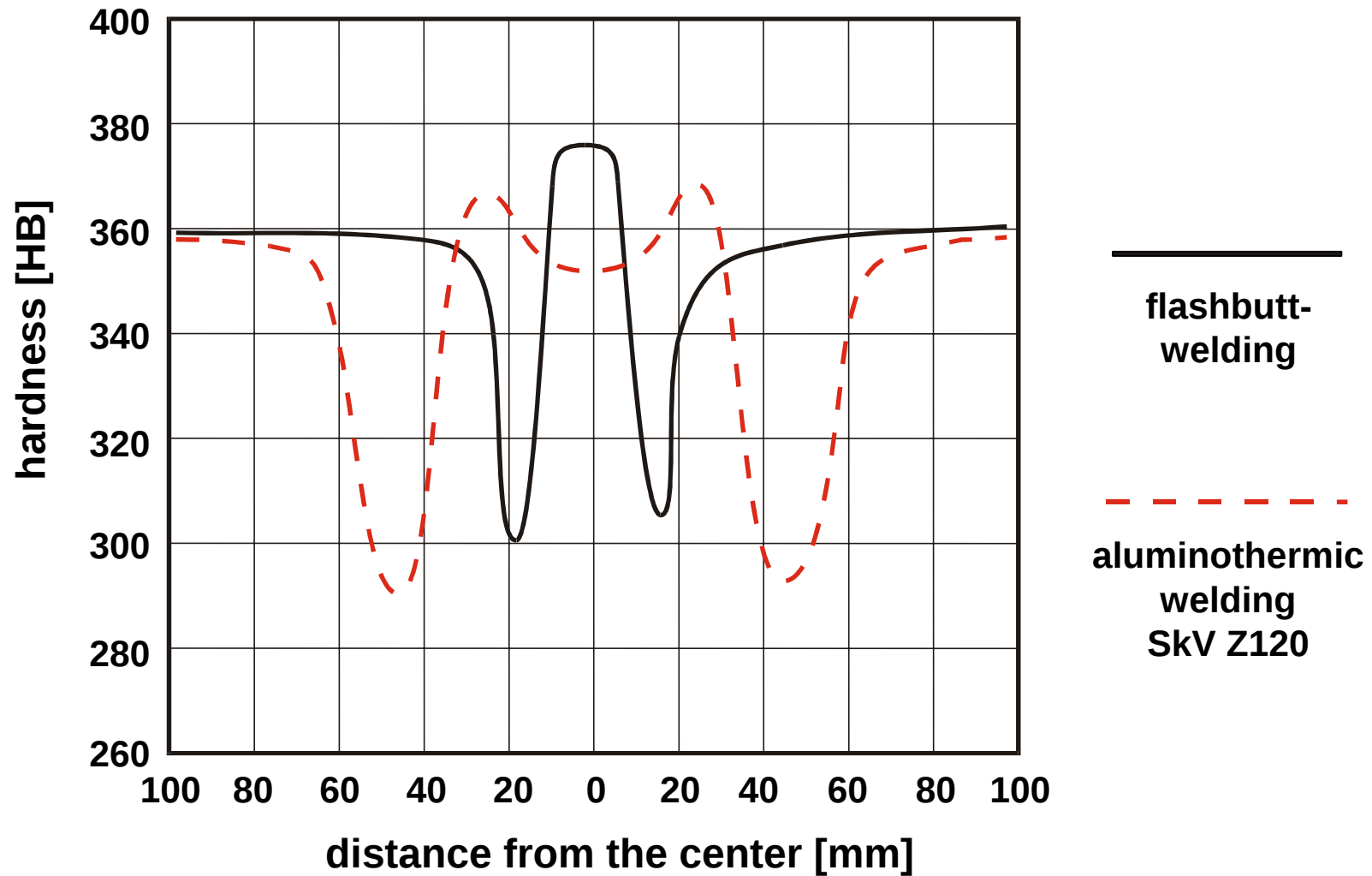
Head Special Hardened Rails



Rail Steel Grades – European Standard

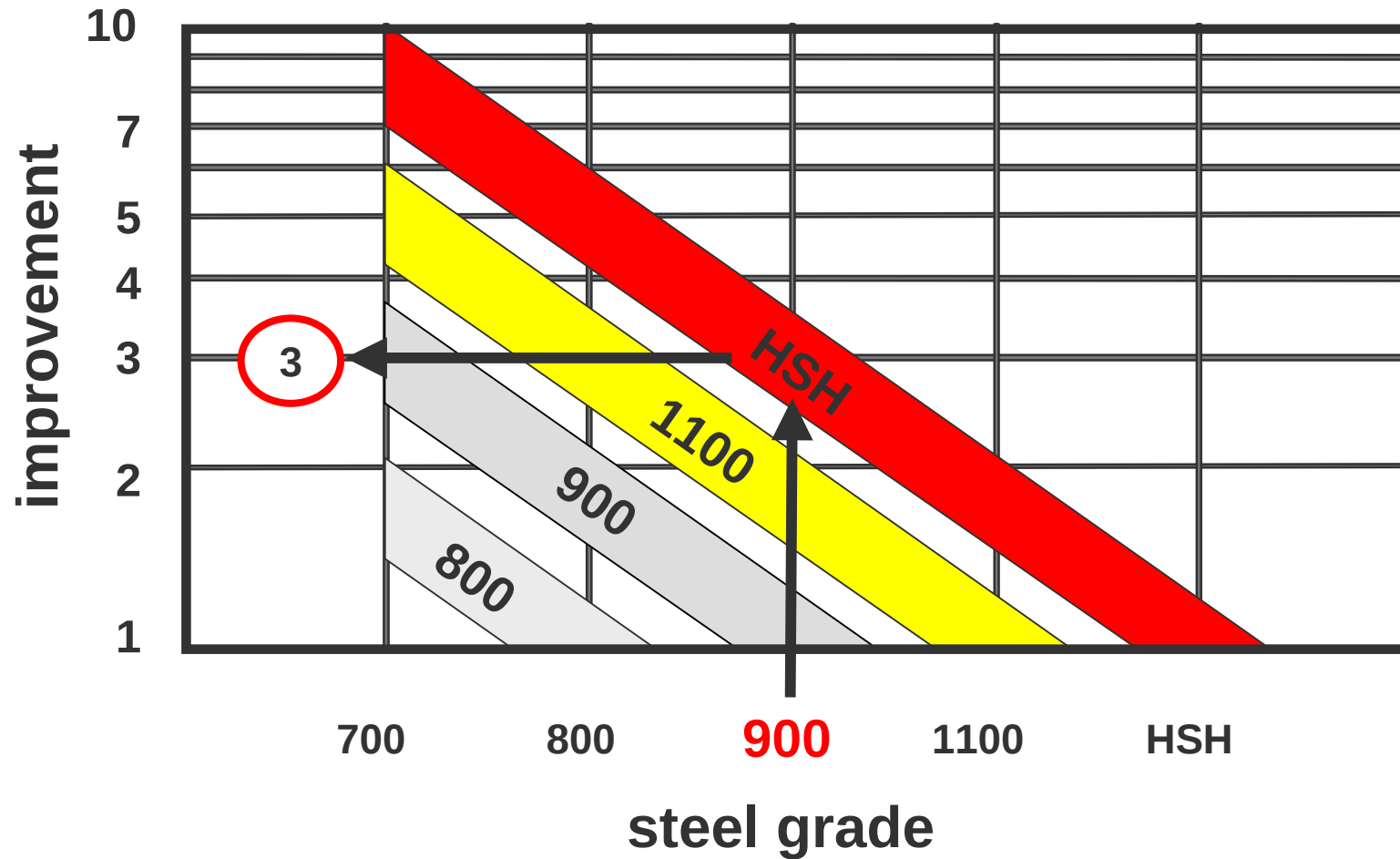
grade	chemical composition (%)						R _m	A ₅	hardness
acc.	C	Si	Mn	P _{max}	S _{max}	Cr	[MPa]	[%]	[HBW]
CEN							min	min	
220	0,50-0,60	0,20-0,60	1,00-1,25	0,025	0,025		770	12	220-260
260	0,62-0,80	0,15-0,58	0,70-1,20	0,025	0,025		880	10	260-300
260Mn	0,55-0,75	0,15-0,60	1,30-1,70	0,025	0,025		880	10	260-300
320Cr	0,60-0,80	0,50-1,10	0,80-1,20	0,020	0,025	0,80-1,20	1080	9	320-360
350HT	0,72-0,80	0,15-0,58	0,70-1,20	0,020	0,025		1175	9	350-390
350LHT	0,72-0,80	0,15-0,58	0,70-1,20	0,020	0,025	<0,30	1175	9	350-390

Width of the Heat Affected Zone



Wear Relations of Different Steel Grades

Head Special Hardened Rails



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Head-Checking Study – Mering/DB

- ❖ high speed track
up to 200 km/h
- ❖ mixed traffic
up to 22,5 to/axle
- ❖ $R = 3300 \text{ m}$
- ❖ highly loaded:
~ 36 MGT/year
- ❖ three steel grades:
HSH, S900A, S800
- ❖ measurements by
FTZ Kirchmöser



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Head-Checks – Results on Pearlites



grade	hard ness [HB]	crack depth [mm]	grind passes
S 800 R 220	240	2,5	20
S 900 A R 260	280	1,5	12
HSR R 350 HT	370	0,5	6



HSH and S1100 on Malmbanan

- ❖ Curve at Torneträsk
- ❖ S1100 rail inbetween 350HT rails
- ❖ Installed 1992



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HSH and S1100 on Malmbanan

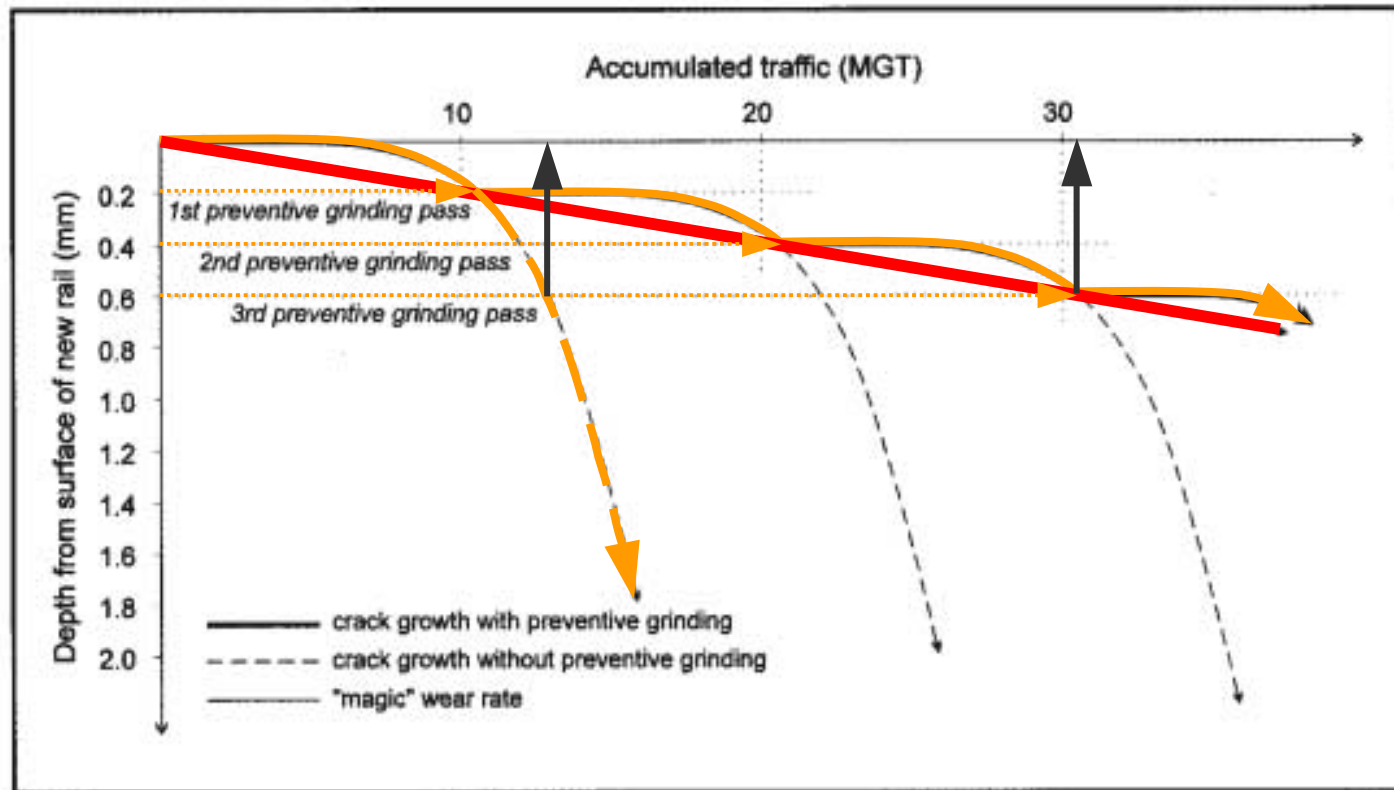
S1100:
Head Checks



HSH – 350HT:
No Head Checks



Maintenance – the „Magic Wear Rate“

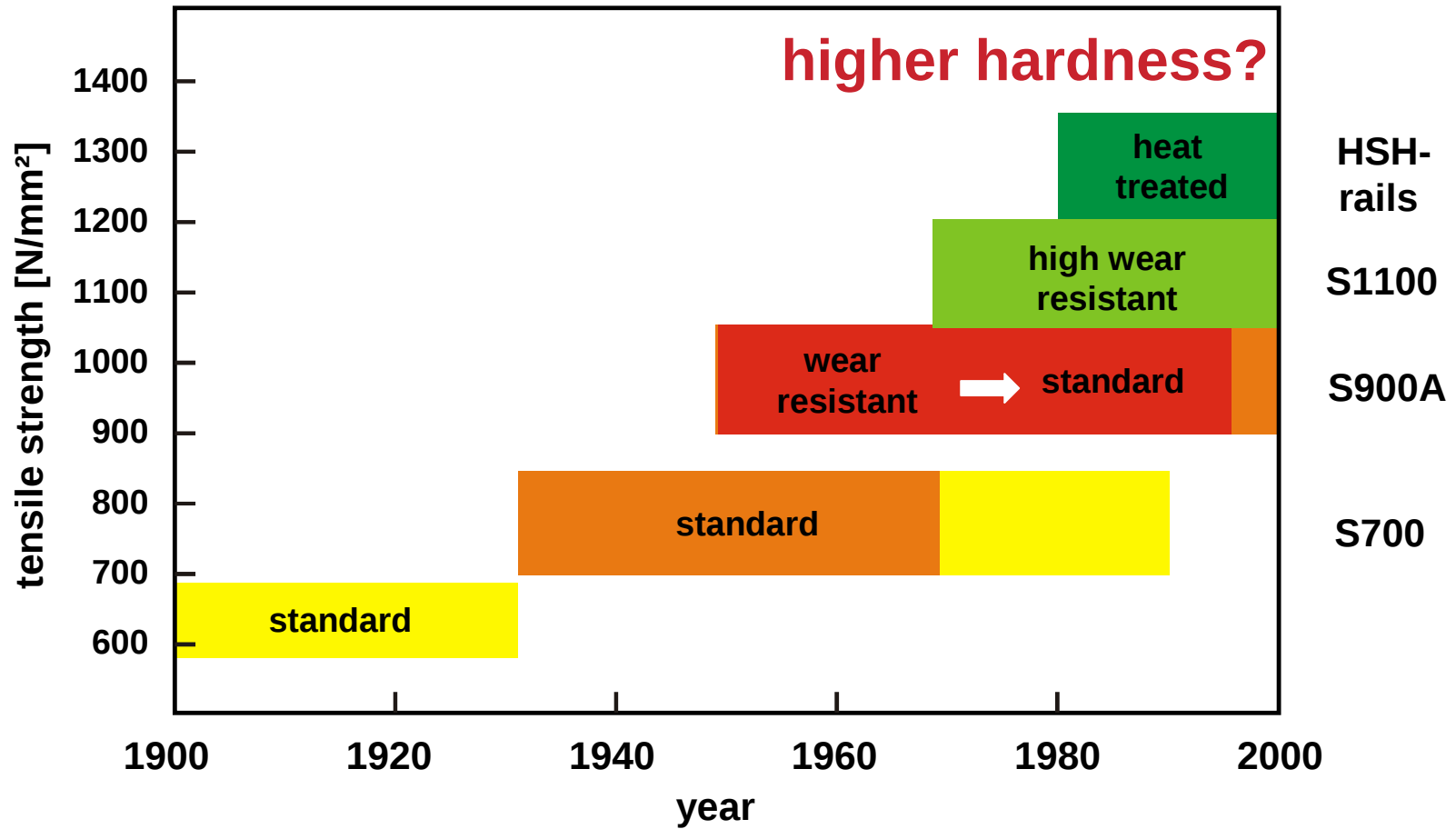


Repeated grinding to take off of the fatigued layer produces a stepped-system, where the rail is worn methodically.

source: J. Kalousek and E. Magel: The "Magic" Wear Rate
RT&S March 1997, pp.50-52

Trends in Rail Steel Development

Head Special Hardened Rails



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Track Testing at the Ofotbahn/Norway

transport of iron ore from Sweden to Narvik/N

90% curves with $R=300$ m

12‰ declination

25 Mio t/year

25 t axle load

Head Special Hardened Rails



Track Testing at the Ofotbahn/Norway

Head Special Hardened Rails



Regular Rail Steel:
S1200
microalloyed
High Wear Rates
Head-Checks



Track Testing at the Ofotbahn/Norway

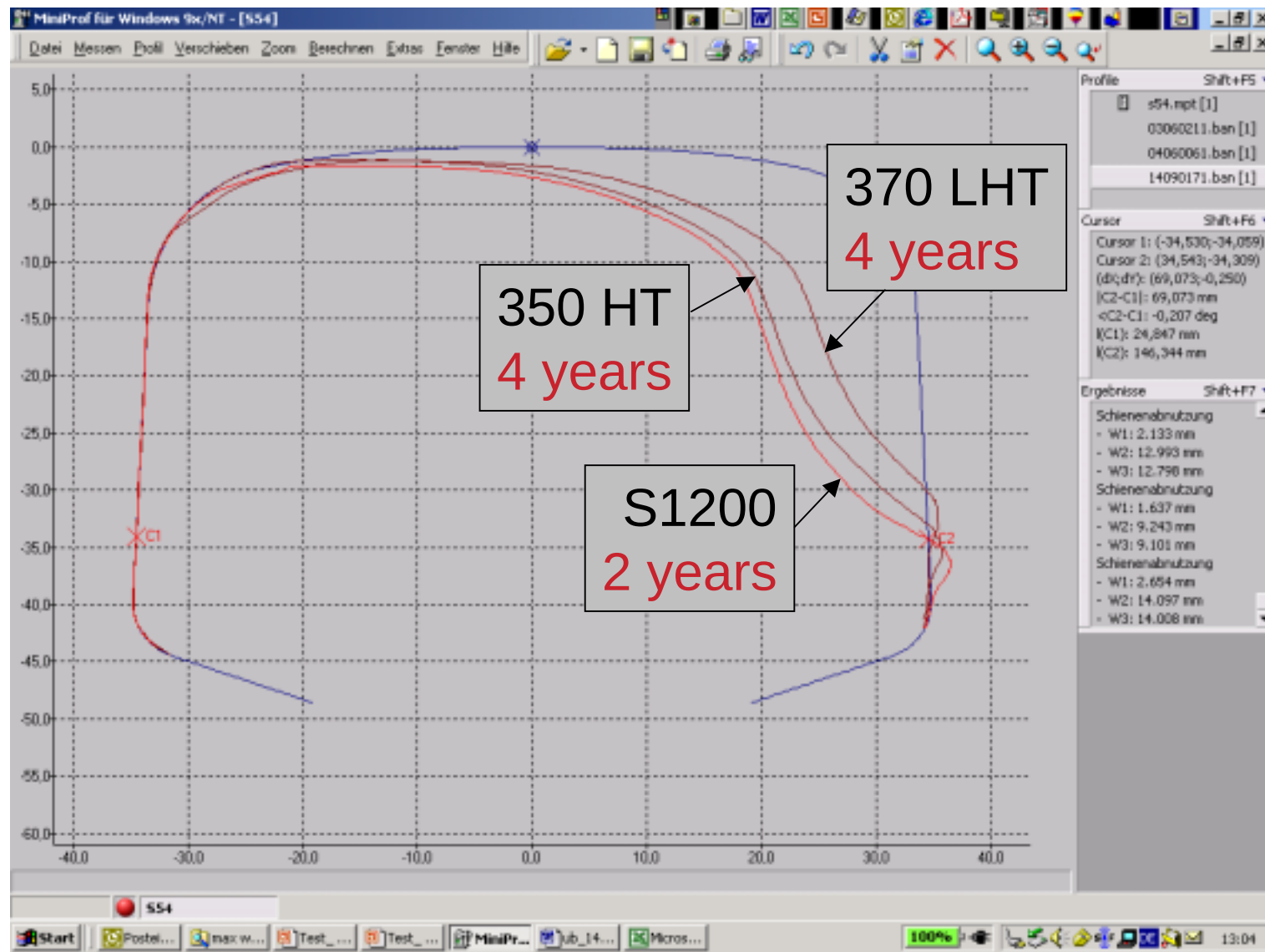
voestalpine's Alternatives:

HSH - Head Special Hardened Steels

350 HT: acc. prEN 13674-1 approx. 370 HB
 max. 0,15% Cr

370 LHT: approx. 0,50% Cr approx. 390 HB

Testing at the Ofotbahn/Norway



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Oftbahn – Rolling Contact Fatigue

Head Special Hardened Rails

350 HT



**less Spalling
on 370LHT**

370 LHT



Recent Developments

- ❖ Look Beyond the Pearlites
- ❖ **Bainitic Rails:**
 - ↪ To combine high RCF-resistance with
 - ↪ High wear resistance
- ❖ Optimize Life-Cycle
- ❖ Lowest Possible Life-Cycle Costs

Bainitic Rail Steels – Concepts

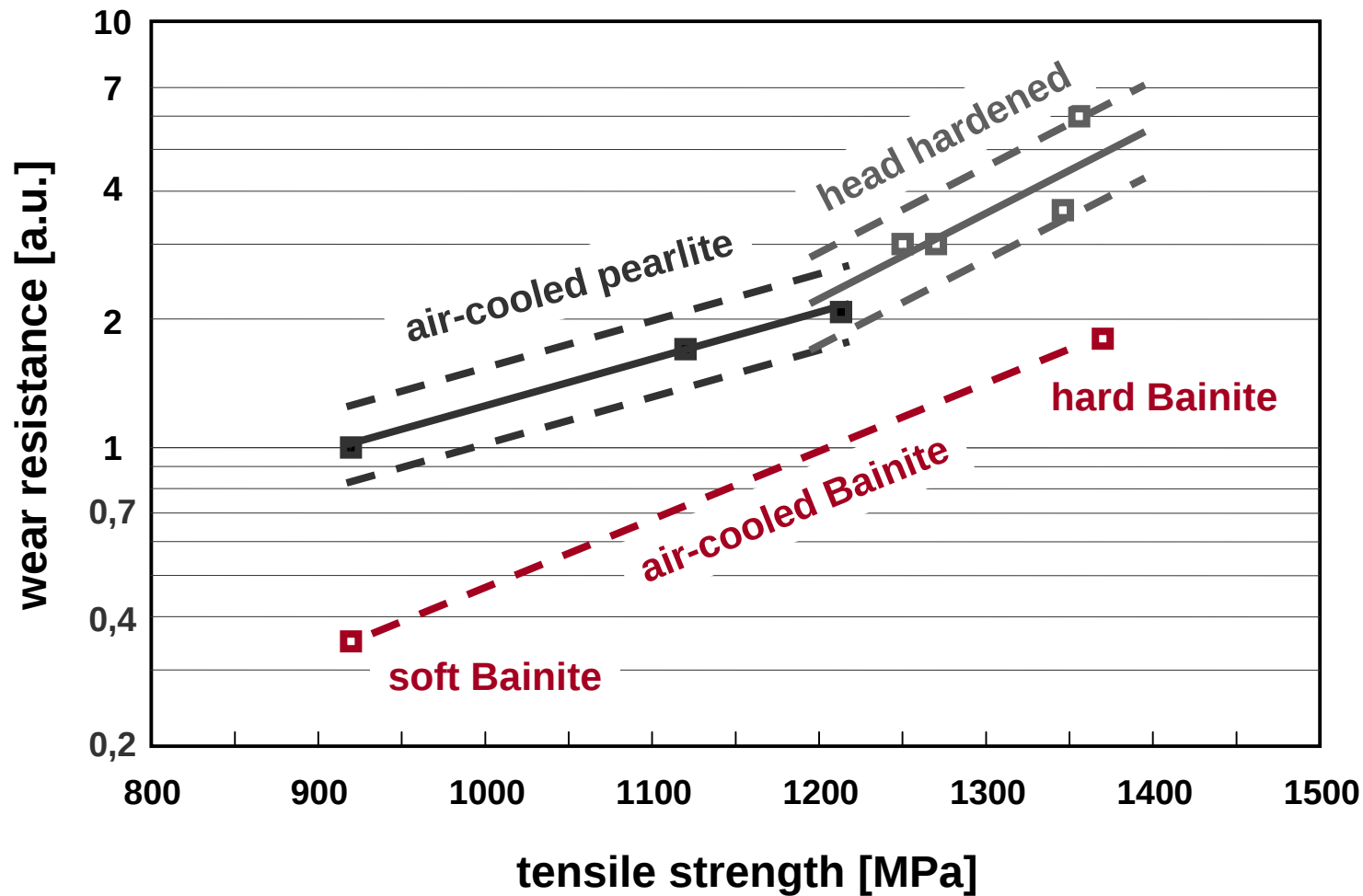
carbide free Bainite:
good against RCF
but low wear resistance

hardened and tempered:
high wear resistance
but technological problems

lower Bainite:
good against RCF and
sufficient wear resistance
voestalpine

Wear of Bainitic Rail Steels

Head Special Hardened Rails



What Is Pearlite? – What Is Bainite?

Pearlite:

lamella of Ferrite and Cementite

Cementite carrier layer as wear depot

fine pearlitic: higher wear resistance

high toughness

Bainite:

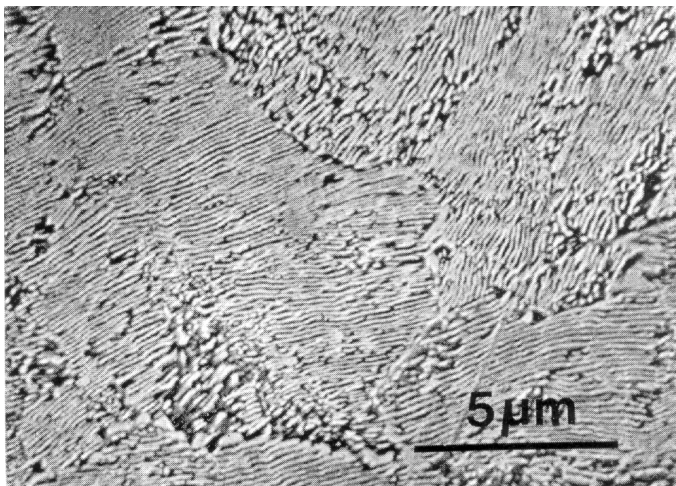
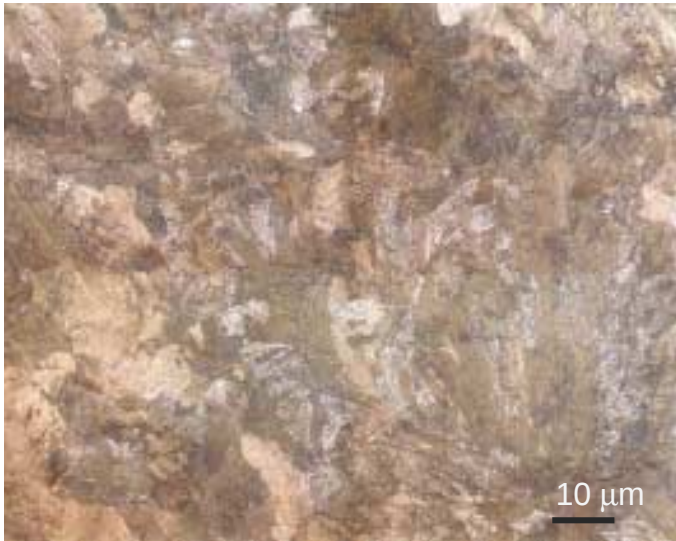
needles of alloyed Ferrite with Cementite platelets

higher hardness achievable

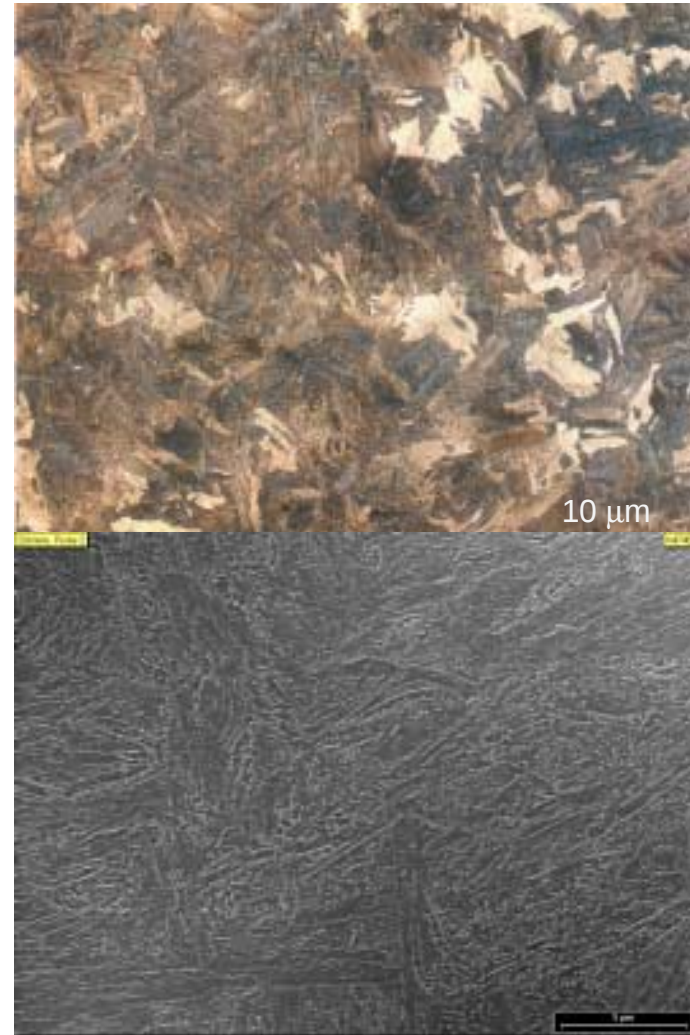
higher yield strength and higher toughness

Microstructure Pearlite and Lower Bainite

PEARLITE



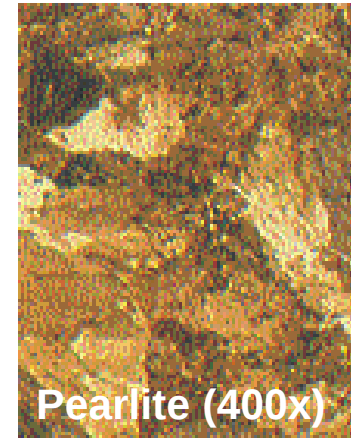
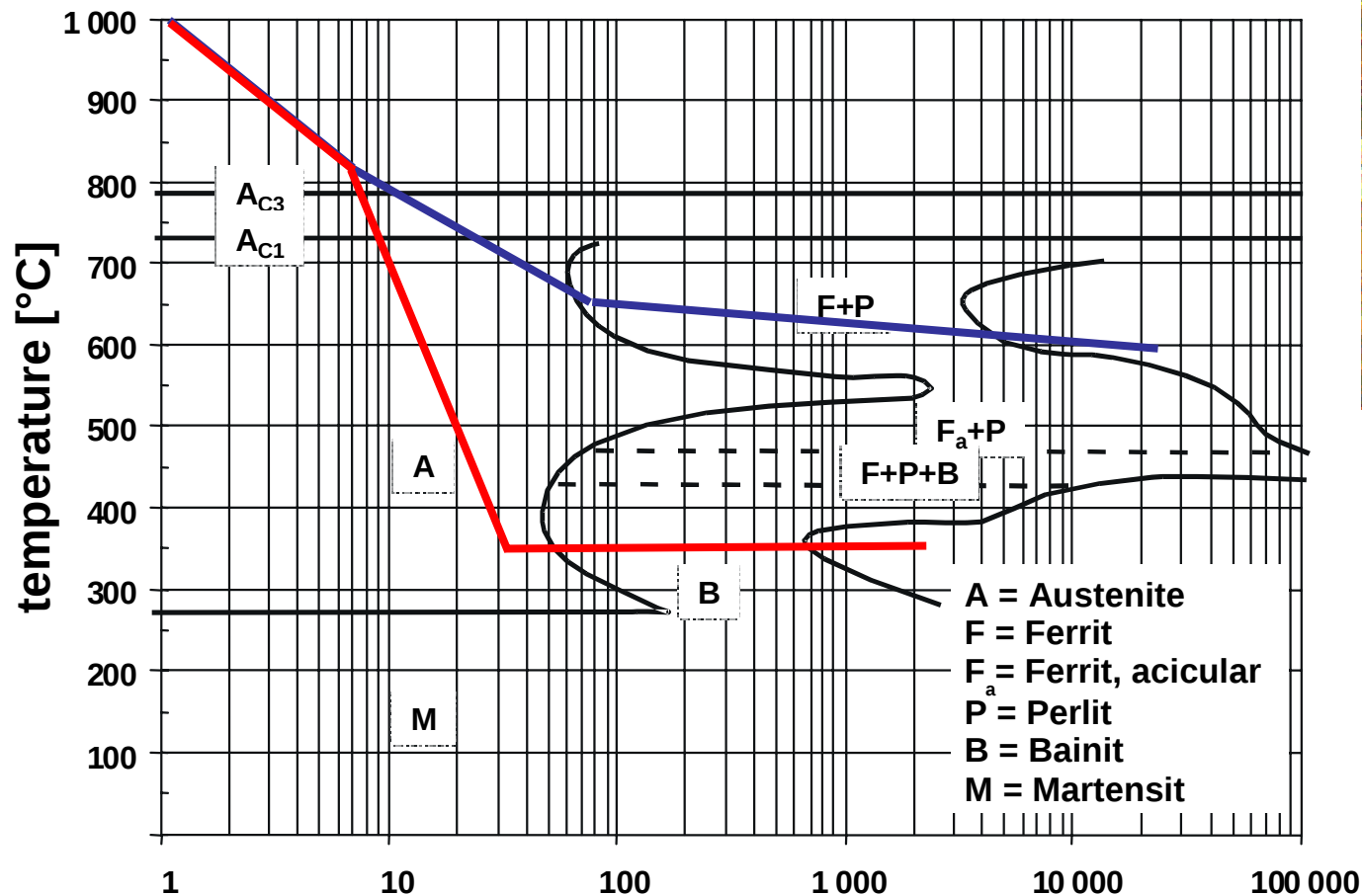
BAINITE



Head Special Hardened Rails

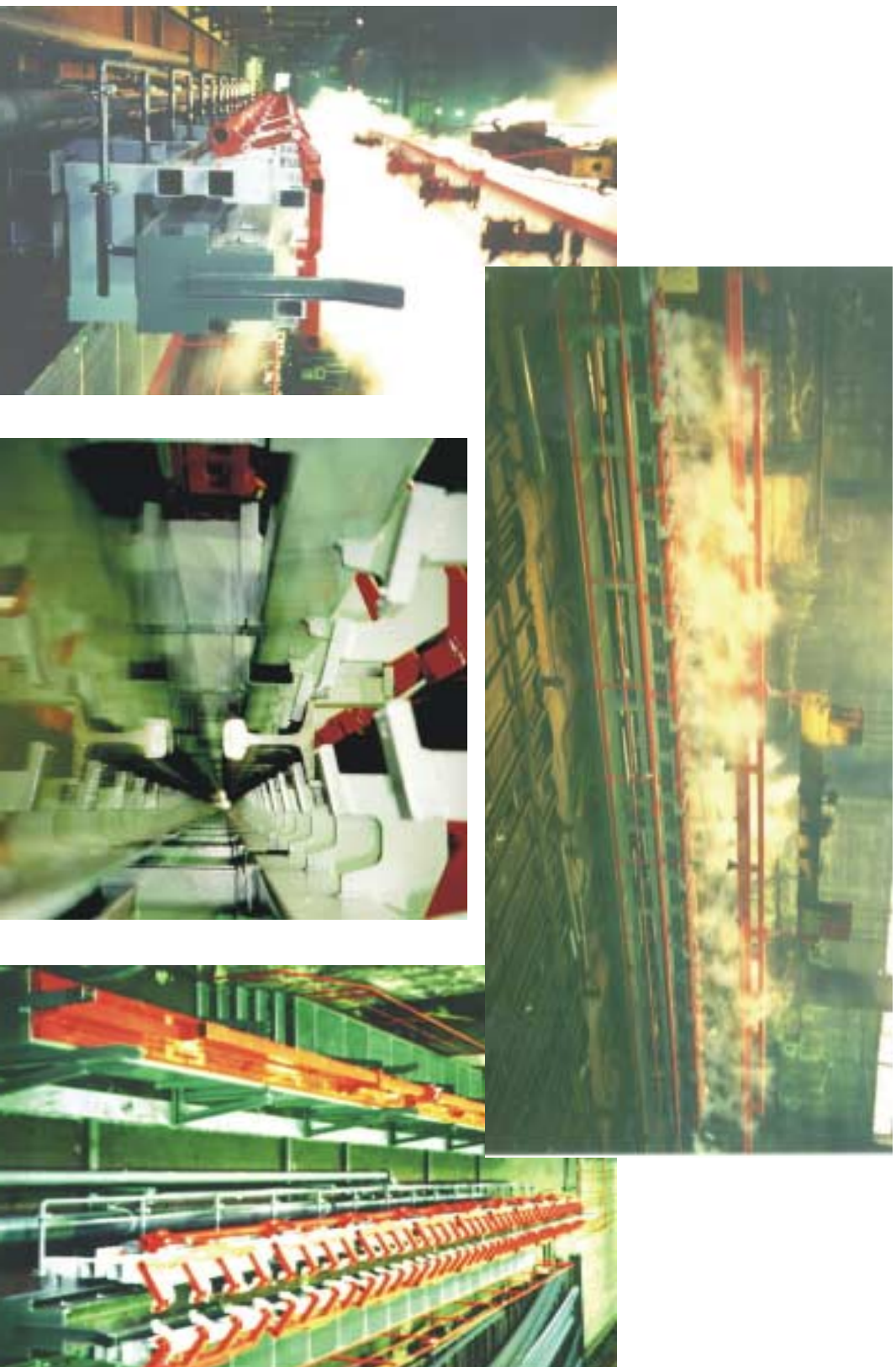
Process Route in the TTT - Diagram

Head Special Hardened Rails



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DOBAIN – Pilot Hardening Plant

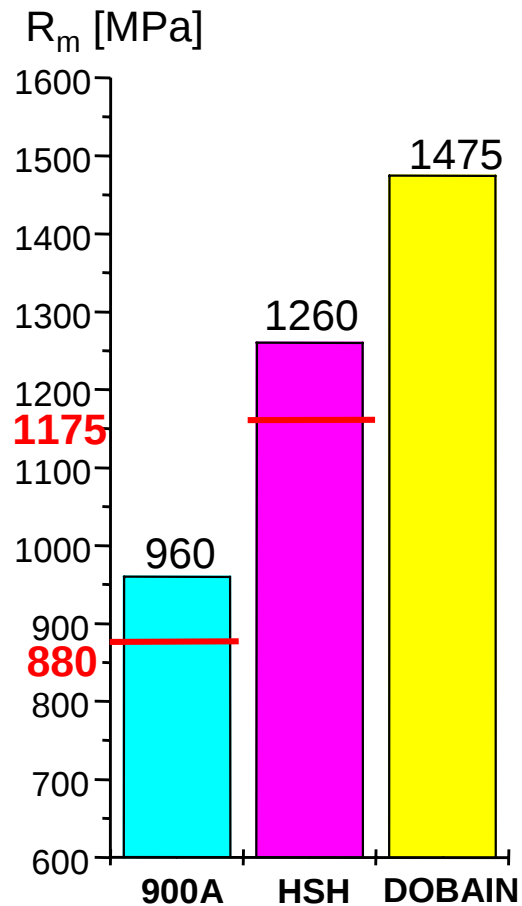


Head Special Hardened Rails

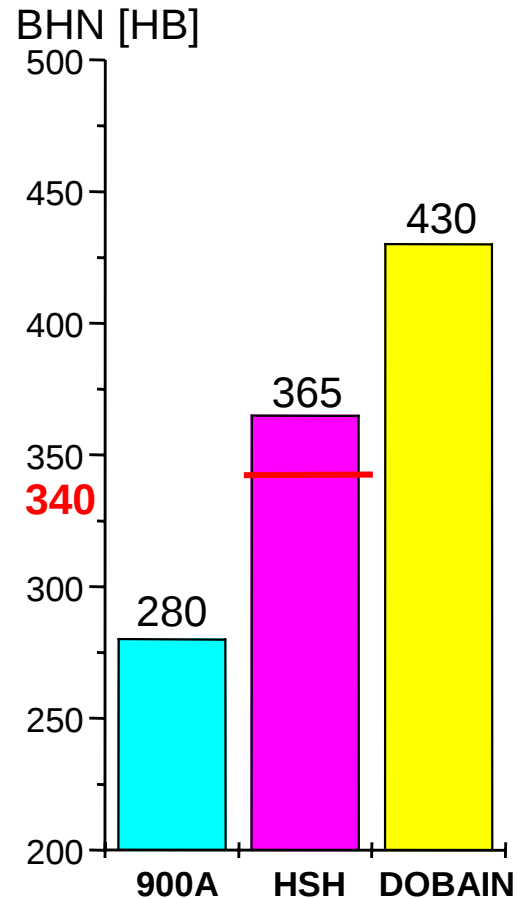
Properties of S900A – HSH – DOBAIN

Head Special Hardened Rails

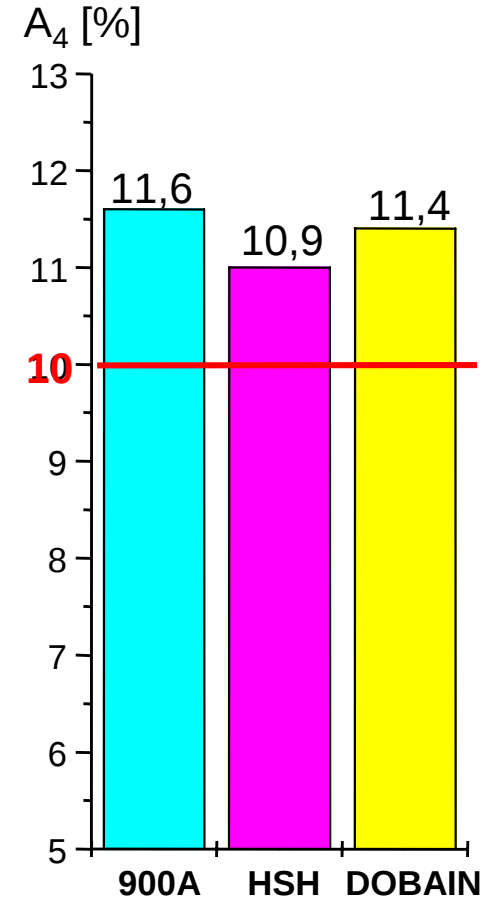
tensile strength



hardness

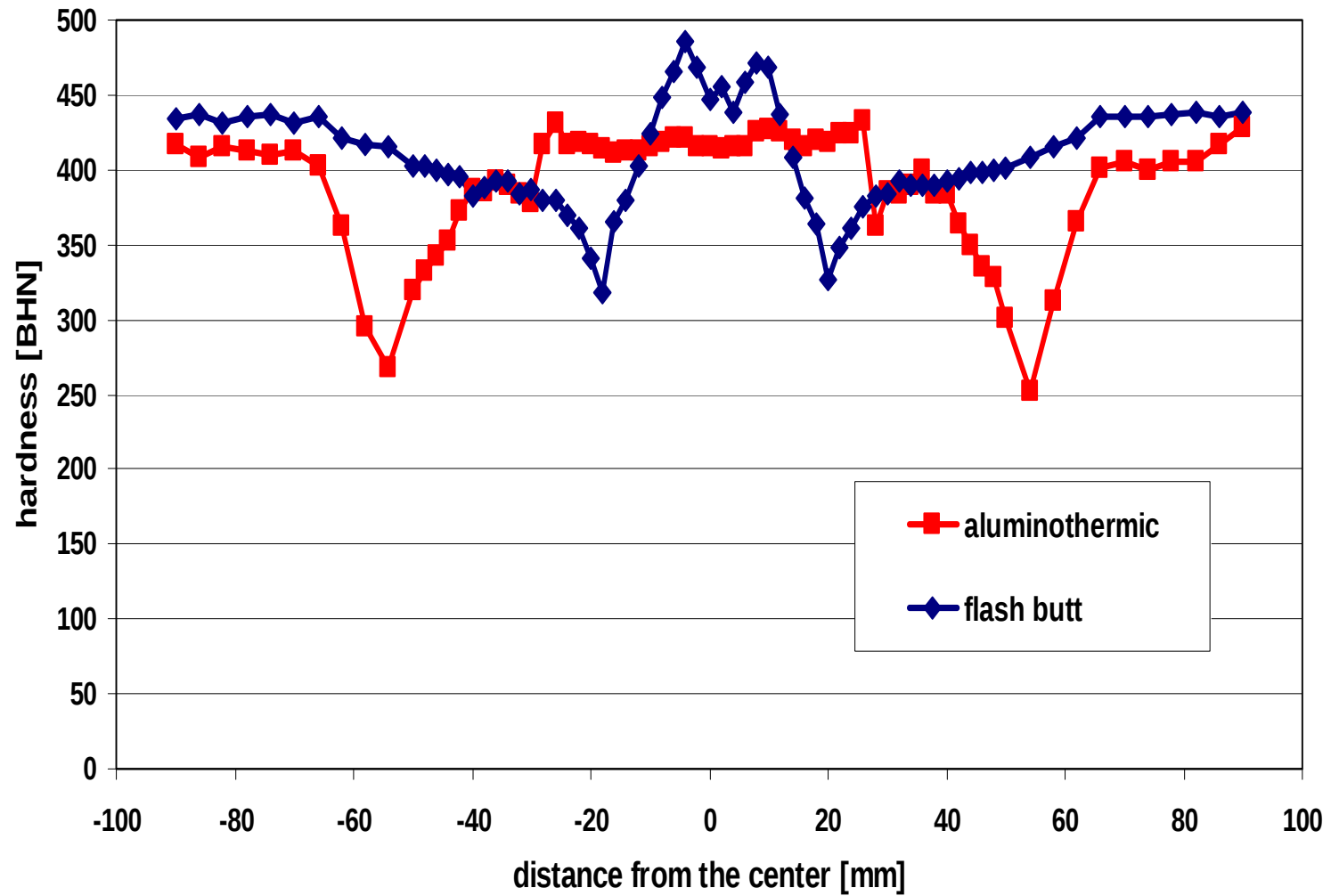


elongation



Welding of DOBAIN

Head Special Hardened Rails



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Semmering – Bainitic Rails

- ❖ mountain track
- ❖ mixed traffic
up to 22,5 to/axle
- ❖ max. 50 mph
- ❖ $R = 185 \text{ m}$
- ❖ $\sim 20 \text{ MGT/year}$

- ❖ two DOBAIN 1 rails
compared to
premium HSH



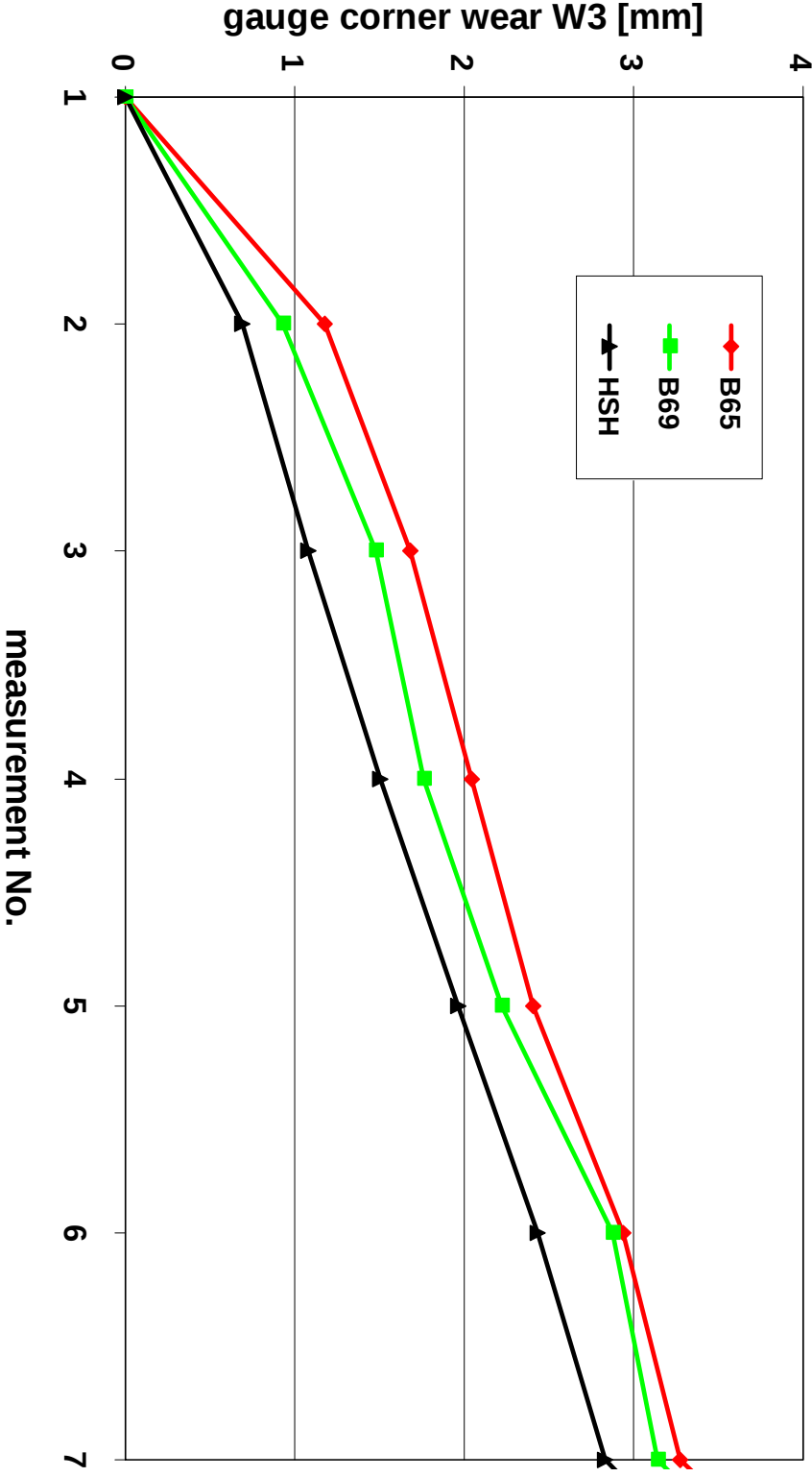
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Semmering – Typical Defects



- ❑ Wear
- ❑ Head Checks
- ❑ Corrugations at the Low Rail

Semmering – Gauge Corner Wear



Head Special Hardened Rails

Semmering – Development of Head-Checks

Head Special Hardened Rails

350HT – HSH
Head-Checks

after 3 years

bainitic DOBAIN
no Head-Checks



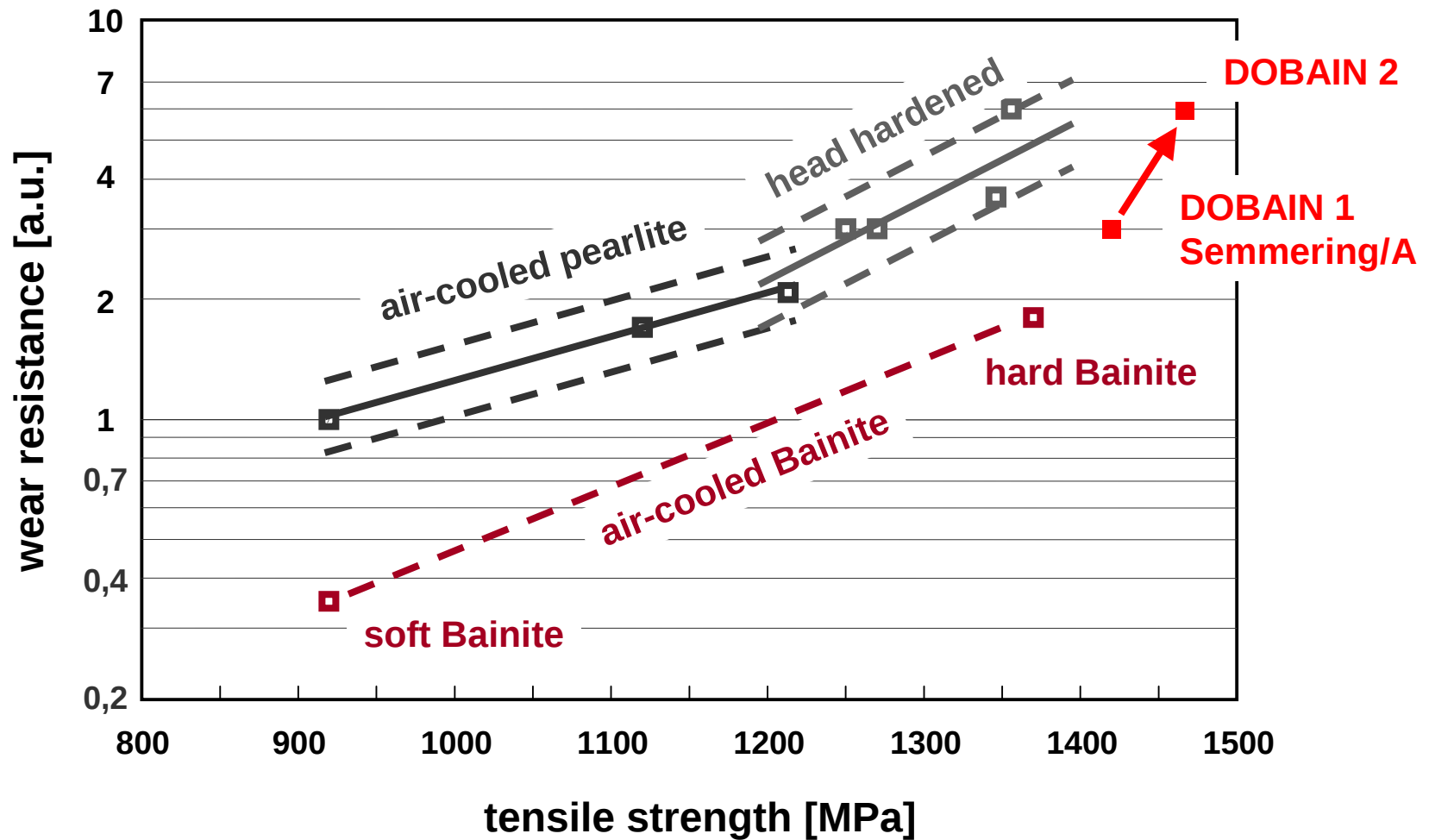
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Semmering/ÖBB – Conclusions

- ▣ DOBAIN 1 Rails tested in wear regime
- ▣ wear resistance close to head hardened
- ▣ RCF resistance larger – no head checks present
- ▣ continue testing to **wear limits**

Wear of Bainitic Rail Steels

Head Special Hardened Rails



DOBAIN 2 – Properties

- ❖ To increase the wear resistance:
- ❖ Adjust chemical composition to higher C-levels
- ❖ Adjust heat treatment to appropriate hardness
- ❖ DOBAIN 430: heavy haul, mixed traffic
- ❖ DOBAIN 380: mixed traffic, high speed, Metro
- ❖ DOBAIN 340: high speed, low axle loads
- ❖ **Goal: no RCF, adjust wear rates acc. to loads**

RWE Rheinbraun – Coal Transport

Head Special Hardened Rails

- ▣ axle load: 35 metric tons
- ▣ R=800m
- ▣ approx. 10 MGT/year
- ▣ max. 60 km/h
- ▣ UIC 60 profile
- ▣ DOBAIN 430 tested and compared to premium HSH



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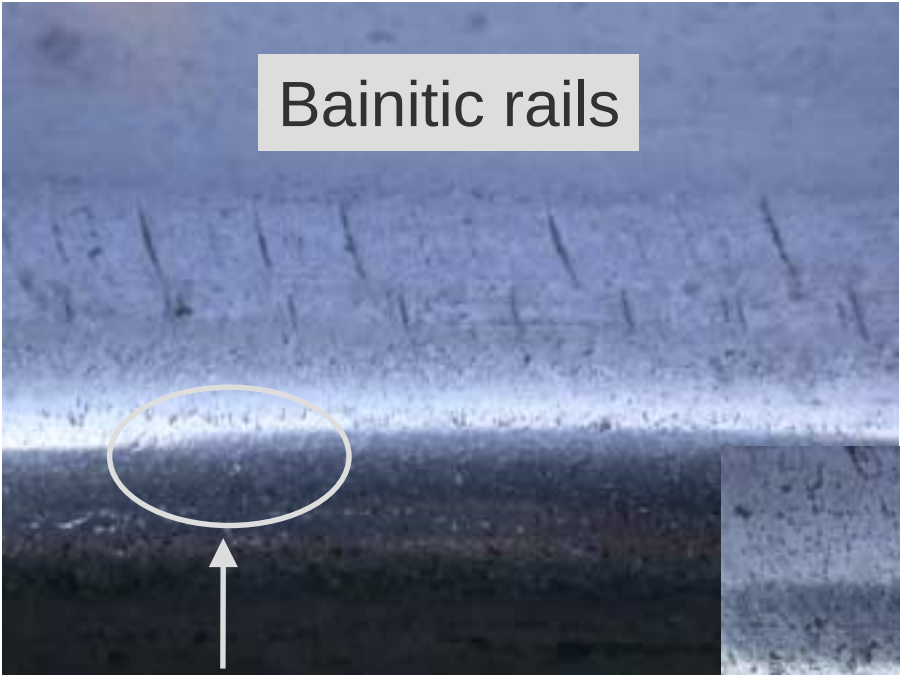
RWE Rheinbraun – Typical Defects

Head Special Hardened Rails



RWE Rheinbraun – Heavy Haul Track

Head Special Hardened Rails

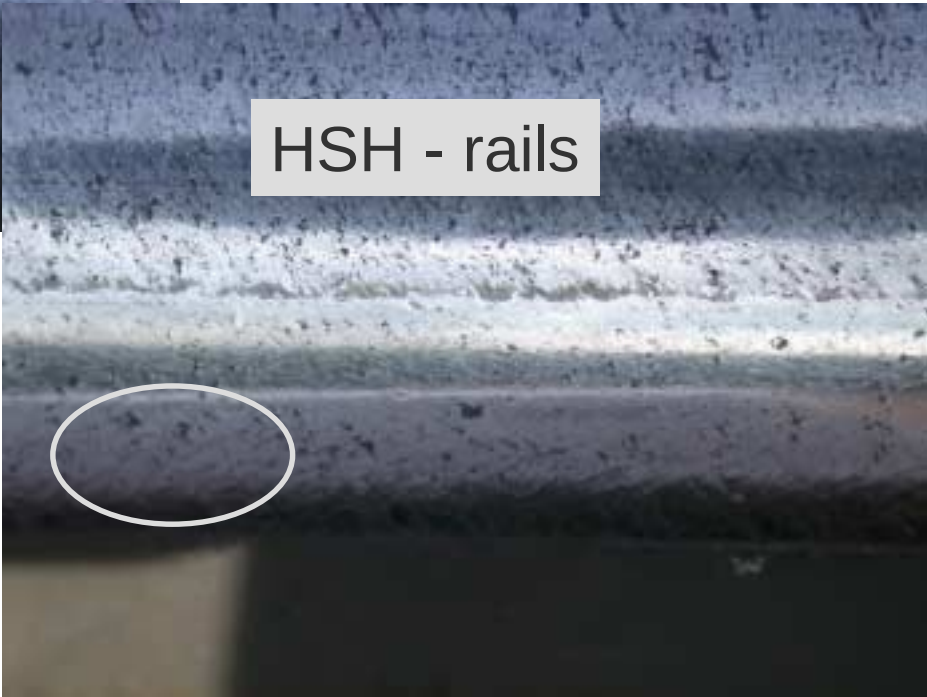


Bainitic rails

after 1 year and
~ 9 Mio to load

No Head - Checks,
surface roughening

Head - Checks



HSH - rails

RWE Rheinbraun – Status

- ▣ DOBAIN 430 Rails tested in RCF regime
- ▣ wear resistance high
- ▣ RCF resistance larger – no head checks present
- ▣ continue testing **until RCF damage starts**

Track Tests with DB AG

- ❖ in high speed and medium speed tracks

Bainitic Rails from voestalpine and TSTG

hardness levels: 430 HB
 380 HB
 340 HB

compared to 900 A and HSH

- ❖ Study of: crack initiation
 crack growth
 wear resistance

Summary and Future of DOBAIN

- ❖ 18 m DOBAIN rails manufactured in a pilot plant
- ❖ mechanical properties superior to Pearlites
- ❖ welding flashbutt and aluminothermic
- ❖ track testing in:
 - wear conditions
 - RCF conditions
 - high speed – starting
- ❖ new hardening plant for DOBAIN rails:
 - 120 m long
 - flatness acc. high speed
 - just-in-time to the site
- ❖ **installed in 2006 together with new rolling mill**