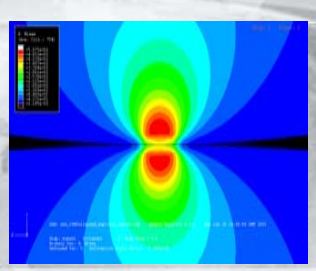
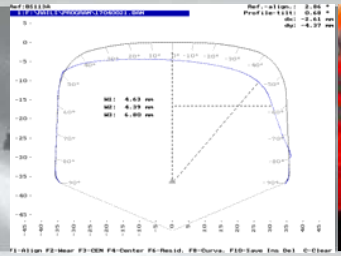
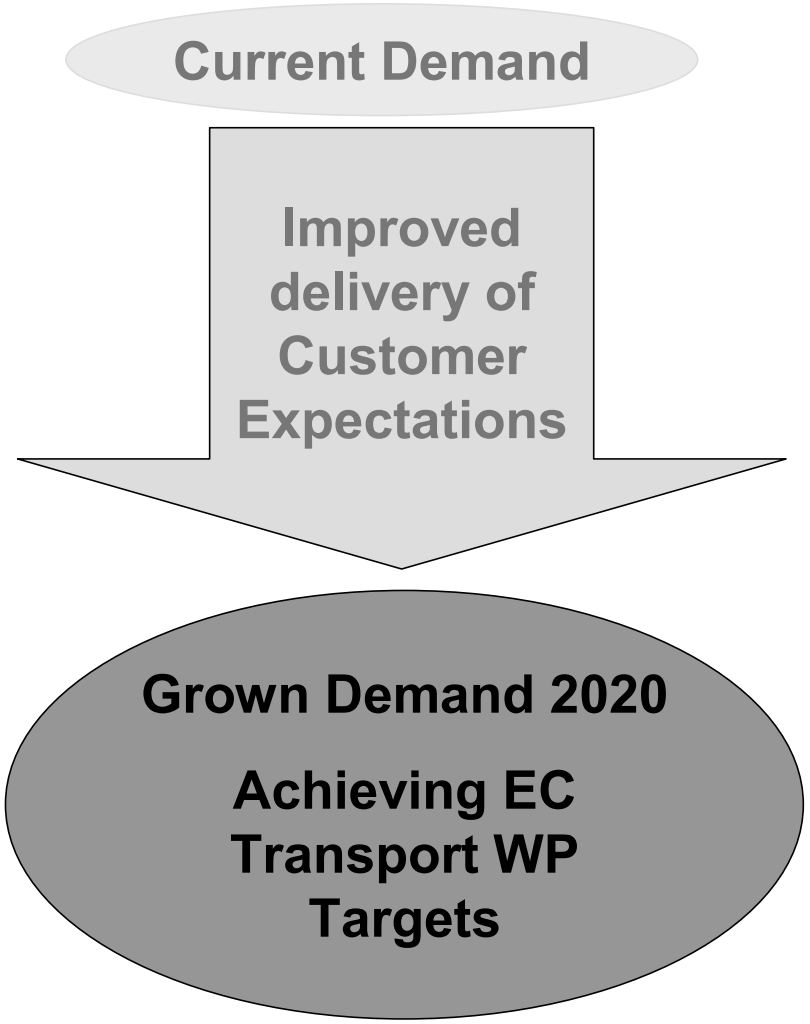
much more than rail


CORUS PREMIUM GRADES TO ADRESS WEAR AND SURFACE FATIGUE

Dr Jay Jaiswal, Pascal Sécordel

Developments in rail retallurgy meeting increasing technical demands



- Double passenger traffic & Triple freight traffic by 2020
- Market Share 15% Freight; 12% Passenger
- Travel time improved by 25% - 50%
- Life cycle cost reduced by 30%
- Noise reduced to 69 dB (A) for freight and 83 dB (A) for high speed
- Increased safety – reduce fatalities by 75%

A Move Towards 24 x 7 Railway

Data from UIC INFRACOST Project

1980 / 1990

RAIL PRODUCTION

Basic Oxygen Converter

Low aluminium killing process

Vacuum degassing

Continuous casting

Ultrasonic inspection

Heat treatment

NEW GRADES

INTERNAL FATIGUE
non metallic inclusions
hydrogen cracks

WEAR

ROLLING CONTACT FATIGUE

WEAR

Traditional approach to counter degradation

much more than rail

HB | U.T.S./ N mm^{-2}

400 | 1300

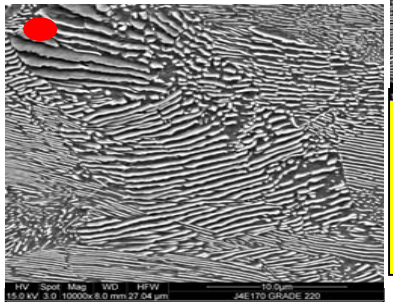
350 | 1200

300 | 1000

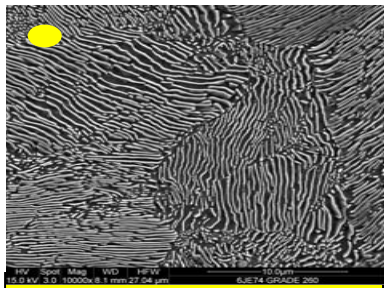
250 | 800

700 | 900

- Increasing hardness
- Increasing strength
- Finer pearlite interlamellar spacing
- Increasing Carbon equivalent

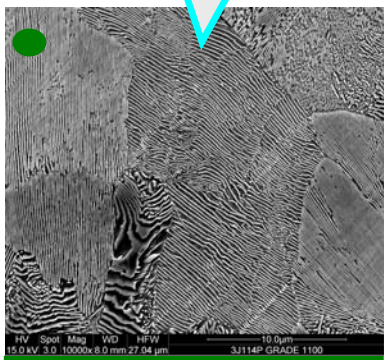


Grade 220:
- Used primarily in UK



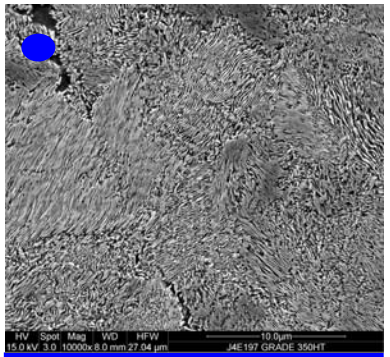
Grade 260

European standard grade, also in RoW
- Asian Mass Transit



Grade 1100:
- Older grade used in Spoornet & BV

Other Intermediate Grades
- Standard NA Grade AREMA 300
- Others: 320V, 320 Mn



Grade 350HT:
- Used in high wear, axle load sites
- Also in mass transits

Other Harder Grades
- MHH
- 370 LHT
- Hypereutectoid Steels

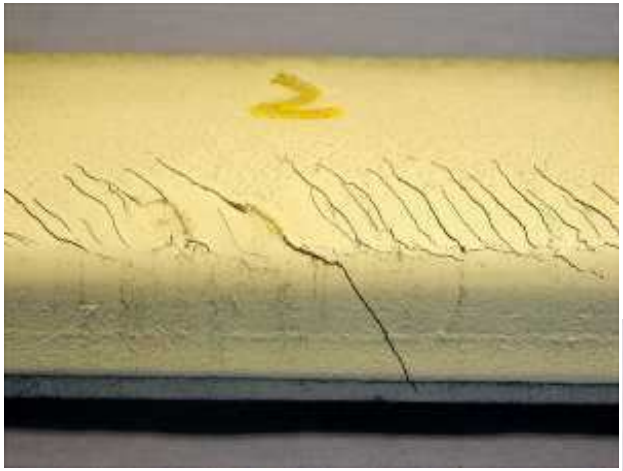
rail steel offerings from Corus

Corus 400 MHH

the latest development Corus HP steel

Corus Carbide-free Bainitic Steels

RCF Cracks – 3D Internal Propagation



head checks typical surface cracks pattern

3D internal propagation of HC cracks

squat defects with turned down cracks

Rail metallurgical developments

Extensive metallurgical studies are important to ensure that rail steels keep pace with the increasing demands of the rail networks

Rail producers must examine all the variables of composition, rolling technology and heat treatment to optimise rail performance

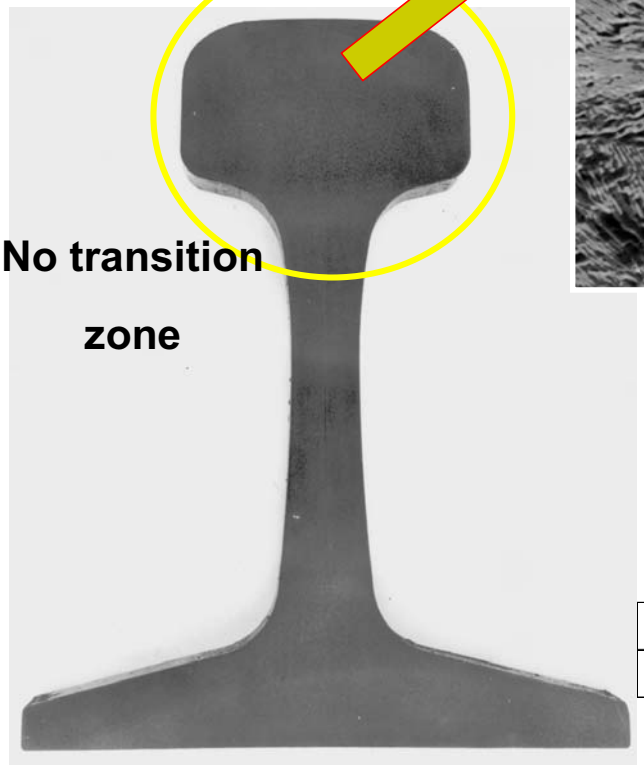
The Corus **MHH Microalloyed Head Hardened rail steel** is the result of combining good chemistry for welding with heat treatment to gain improved properties against wear and rolling contact fatigue

The major railways are evaluating MHH for difficult track applications involving wear and RCF

Results from completed trials indicate exceptional performance on both European and North American tracks

MHH: High hardness and ductility

much more than rail



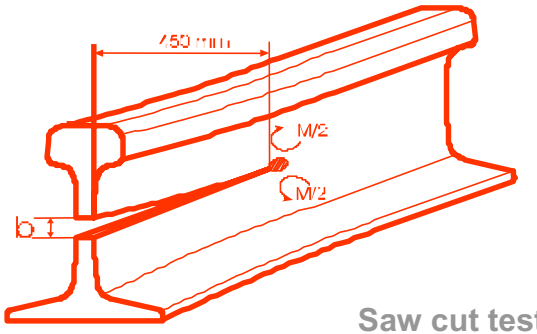
Mass %								
C	Mn	Si	Cr	P	S	Cu	Ni	Mo
0.77	0.91	0.66	0.46	0.017	0.011	0.021	0.017	0.001

	Yield Strength Mpa	Tensile Strength MPa	Elongation (%)	Reduction of area (%)	Brinell Hardness surface	Brinell Hardness 20 mm below rail surface
Minimum	830	1280	12	35	375	352
Average	870	1300	14	42	395	370

MHH : optimised residual stresses

No roller straightening is required after heat treatment

The straightness of the rails is achieved on the heat-treatment facility by an accurate adjustment of the cooling parameters



Saw cut test

$$K_T = \frac{M}{\sqrt{2\,bl}} < K_{Ic}$$

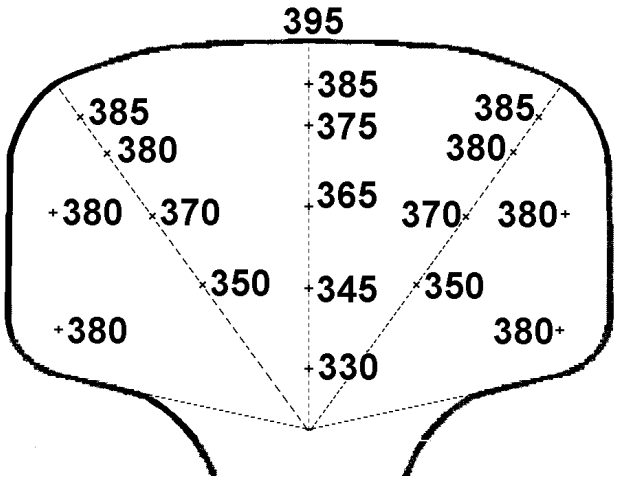
Conditions	Longitudinal stresses (MPa)			Saw cut test (mm)
	Head	Web	Foot	
Natural cooling before straightening	+30	-20	+30	+0.2
Natural cooling after standard straightening	+180	-160	+220	+1.8
Natural cooling after optimised straightening	+140	-110	+190	+1.5
Off line heat treatment without straightening	-86	+41	-30	-1.5

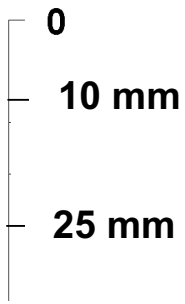
MHH : consistent metallurgical results

Compared to other on line heat treatments, our process has the following advantages :

- constant entry temperature : constant temperature before cooling

- the rail is moving under air nozzles : constant cooling speed





Homogeneous and consistant mechanical properties along the rail, and through its section

MHH : consistent mechanical results

	Rm (MPa)	Al (%)	Hardness (HB)
R260	980	12.2	280
R350HT	1 260	11.3	370
R350LHT	1 280	11.5	380
MHH	1 330	12.9	400

Corus MHH tests

much more than rail

Completed :

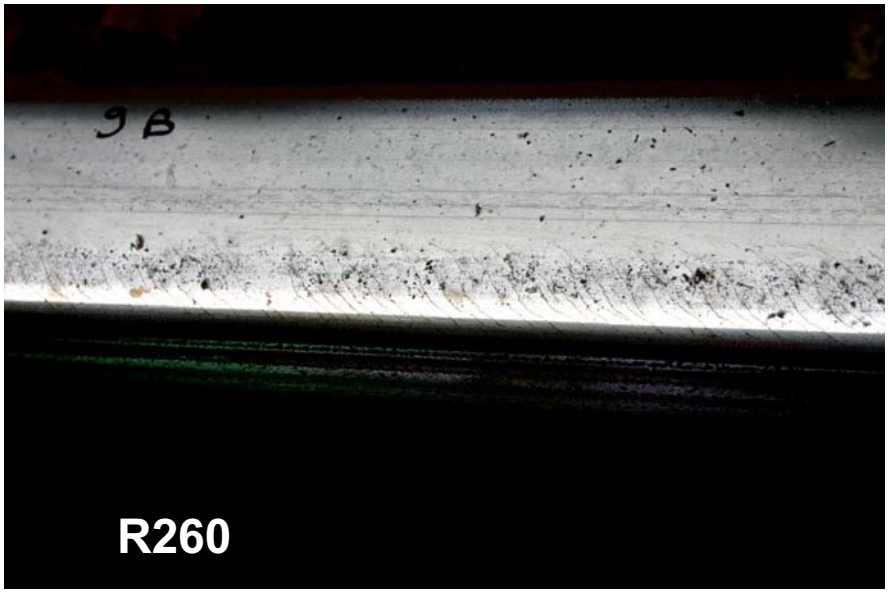
- SNCF St Benoit : MHH <-> R220, R260, R260Cr
- FAST Pueblo: Rail performance evaluation test: MHH <-> Standard High Strength, UHC, bainitic
- ProRail Bunnik : MHH <-> R260Mn
- Union Pacific Tehachapi Megasite : MHH <-> Standard High Strength, UHC
- OBB Eichgraben : MHH <-> UHC, R350LHT, R370LHT
- SNCF Survilliers : MHH <-> R260
- Estonia Tallin : MHH <-> R350HT

In progress:

- Eurotunnel F and UK loops : MHH<-> R350LHT
- RATP : MHH <-> R260
- SBB : St Gothard track (reference 350LHT)
- DB Rhine valley MHH : <-> R350HT

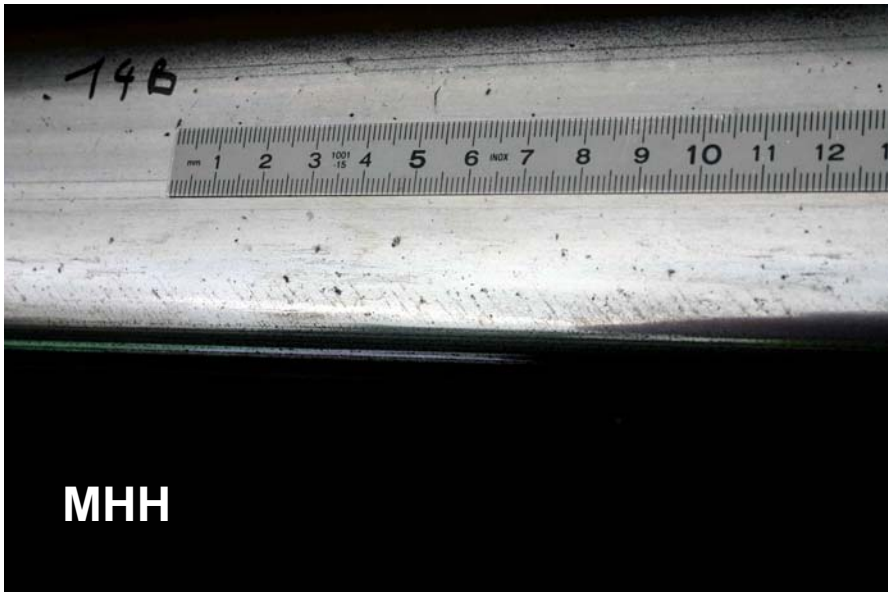
MHH tests in track – SNCF St Benoit – head checks

much more than rail



Radius : 985 m

Speed : 120 km/h



After 175 MGT

Long and deep cracks on R260

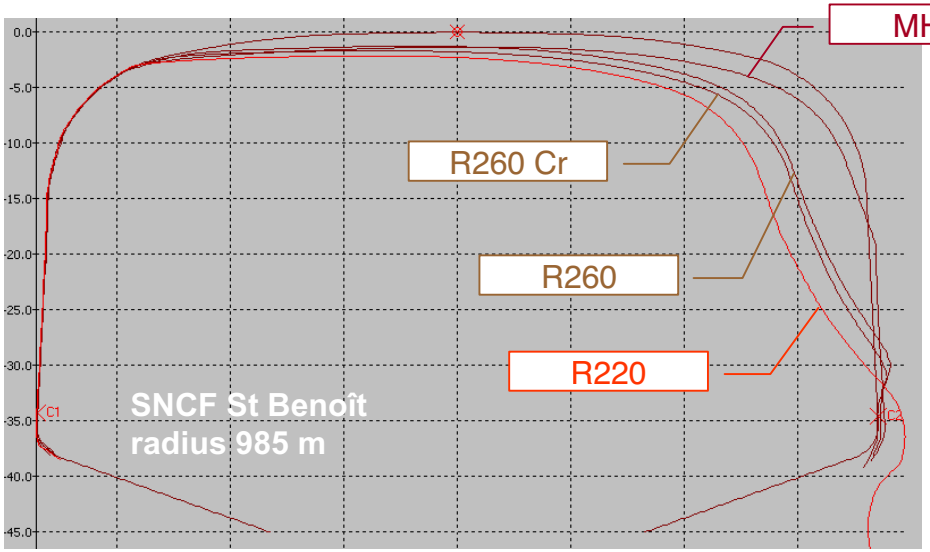
need to be grinded

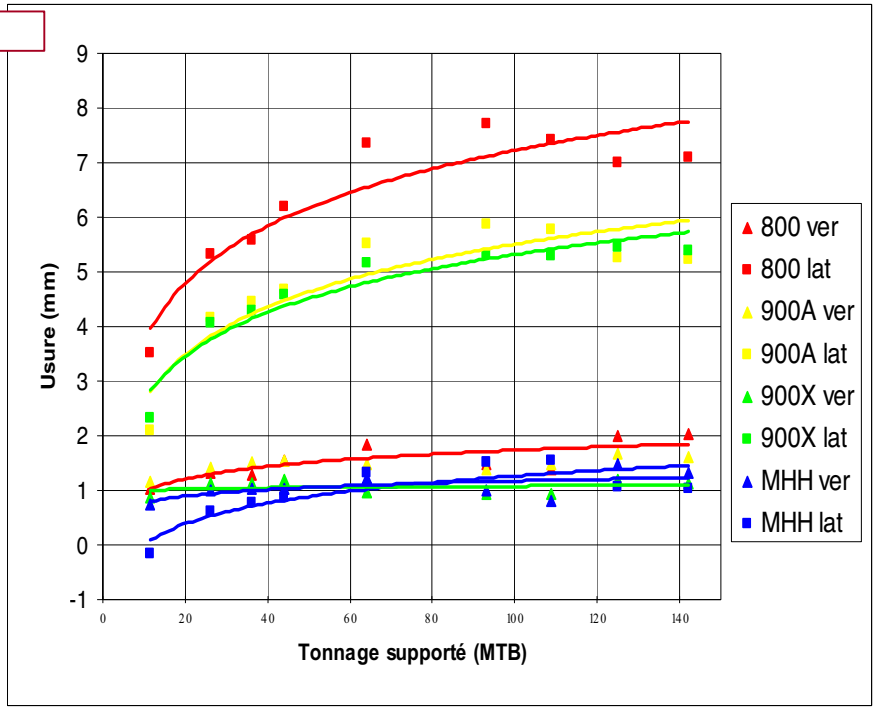
Short and very shallow cracks on MHH

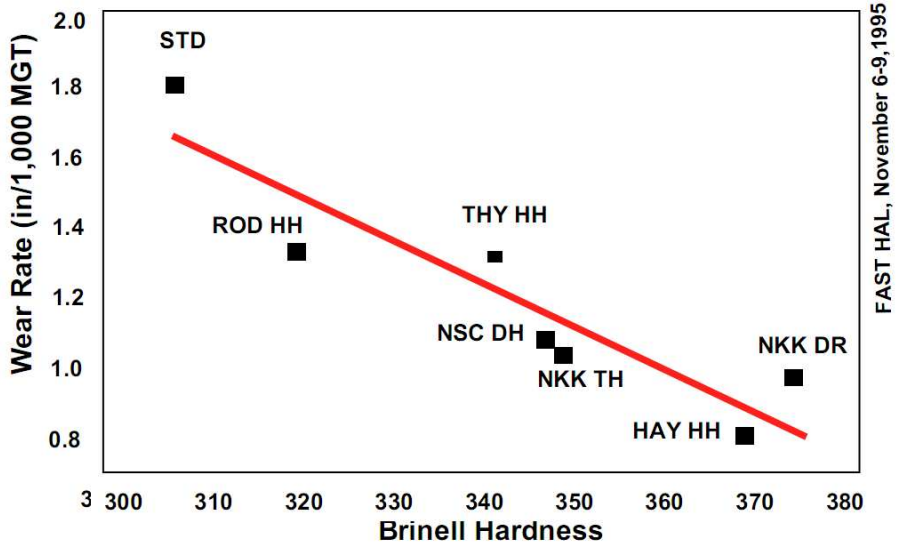
A grinding is not necessary because the wear is sufficient to remove surface fatigue microcracks

MHH tests in track – SNCF St Benoit - wear

much more than rail







- The lateral wear is linked to the position of the rail in the curve (maximum values in the middle of the curve)
- The rate of lateral wear is stabilized and there is practically no wear on the MHH
- The MHH wears five times more slowly than the grades 900

MHH tests in track – Prorail Bunnick
wear & head checks

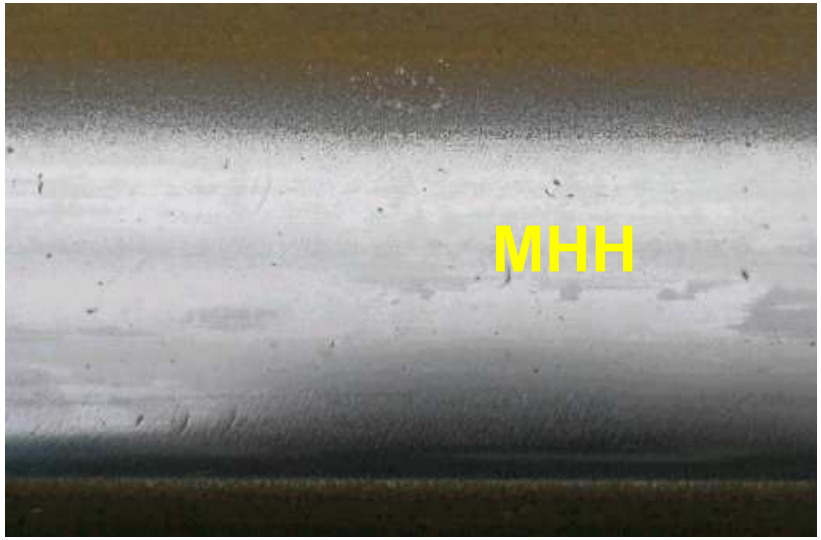
much more than rail

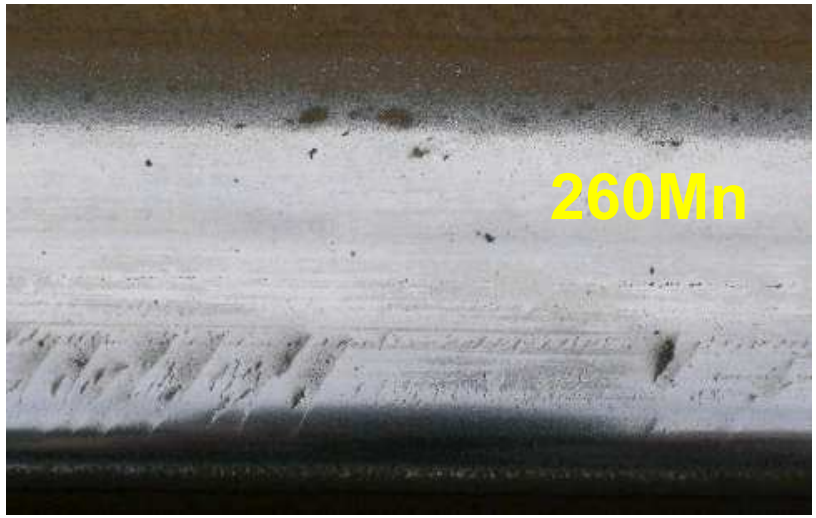
ProRail, Utrecht region (Bunnik), radius 2275 m, reference R260Mn, 2000

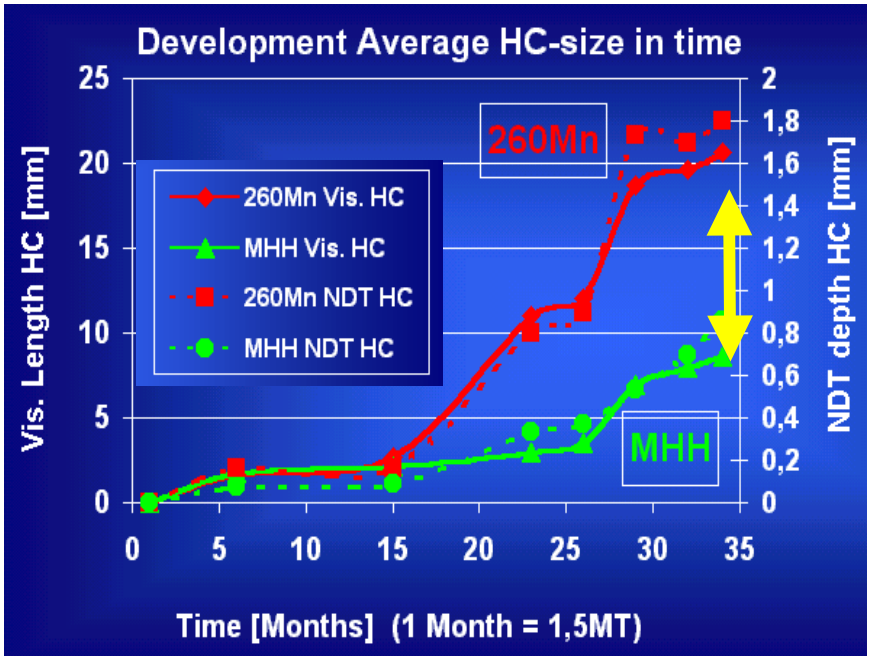
Studied parameters: steel hardness, wear and RCF (MHH)

Advantage confirmed for MHH

much more than rail







In the first 45MGT the MHH rail has a better resistance against HC growth than the 260Mn rail-material. However once the small cracks have initiated and start to grow, the HC-size seems to develop in MHH as far as in 260Mn.

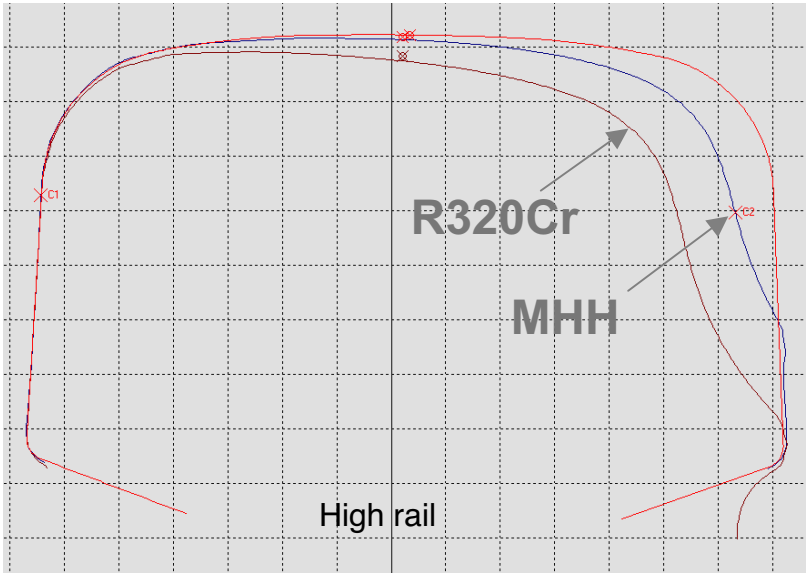
The slower crack-growth-rate of the MHH in the early stage of crack development can be explained from its finer microstructure.

17 kt of " MHH head check retarding rails" have been laid in Holland according to the following recommendations

Curve	High rail	Low rail
Radius > 3000 m	R260Mn	R260Mn
2200 < R < 3000 m	UIC 5 & 6 : R350HT	R350HT
	UIC 1 to 4 : 370LHT	R350HT
1500 < R < 2200 m	MHH	R350HT
R < 1500 m	MHH	R350HT

MHH tests in track – SBB St Gothard - wear

much more than rail

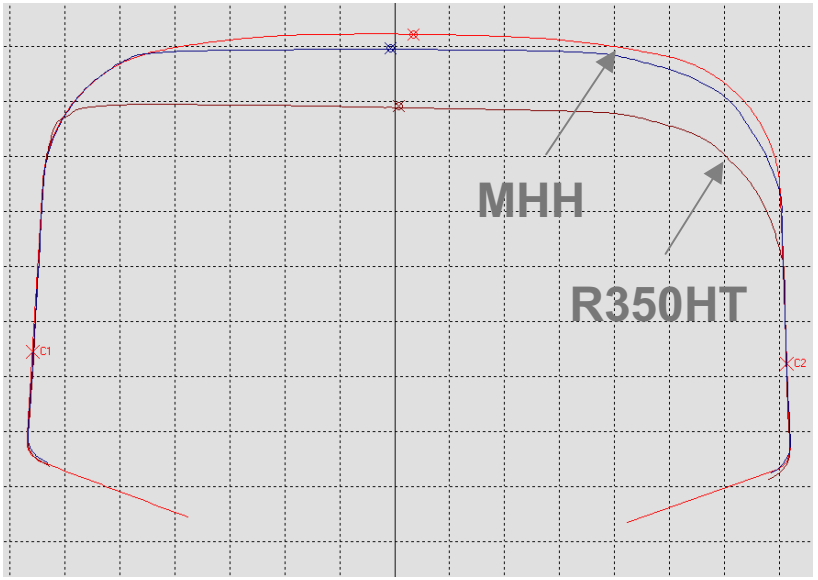


SBB St Gothard tunnel
radius 300 m
mixed traffic

reference R320Cr (HR)
R350HT (LR)

Compared wear on high rails and low rails, after 65MGT

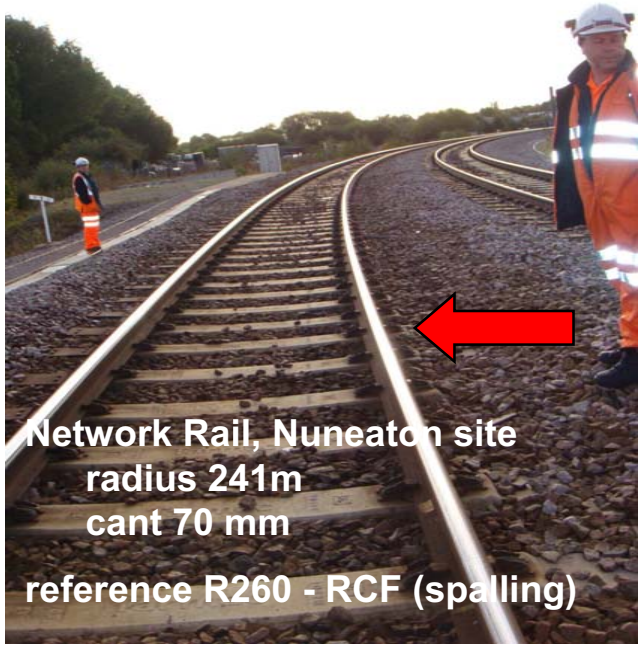
Light head check on MHH, but continuously removed by wear on the high rails



MHH tests in track – NR Nuneaton - spalling

much more than rail

R260



MHH

RCF remains light with MHH, and severe with R260 (spalling)

Up to 2 mm grinding is necessary to remove successfully the cracks

Conclusion -Performance in Curves

much more than rail

MHH gives the best results against wear and RCF

Residual stress distribution limits the crack propagation and makes it possible to grind less often

About 200 KT sold in
- **Brasil**
- **Mauritania**
- **Holland**
- **Estonia**
- **Australia**
- **UK**

Latest Development : Corus “High Performance” HP Rail

much more than rail

Corus “High Performance” (HP) Rail

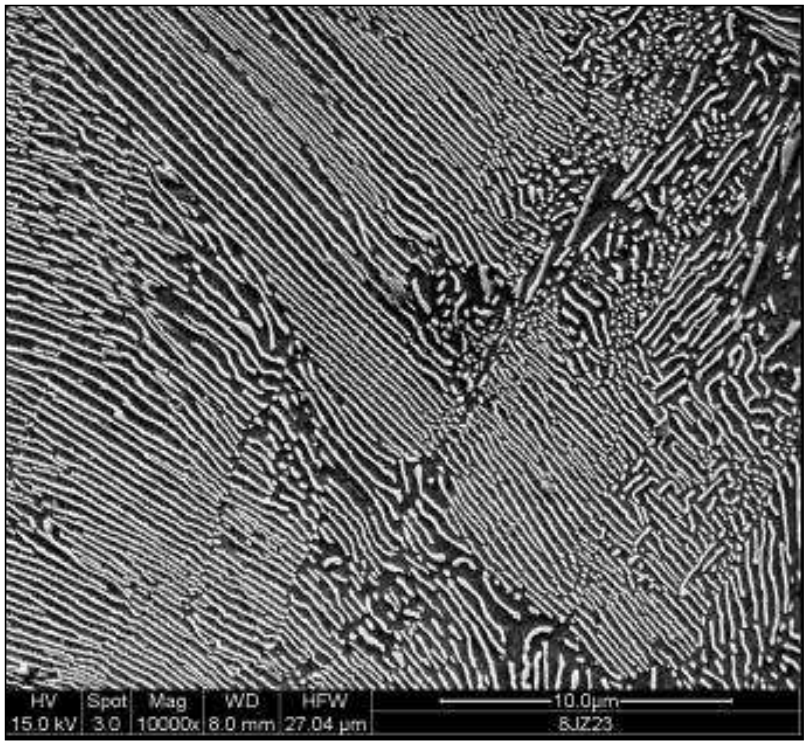
- Metallurgically Engineered Pearlitic Rail Steel
- Reduced pearlite lamella spacing
- Increased strength of ferrite

Improved Properties

- Improved Wear resistance
- Significantly improved RCF resistance

Availability:

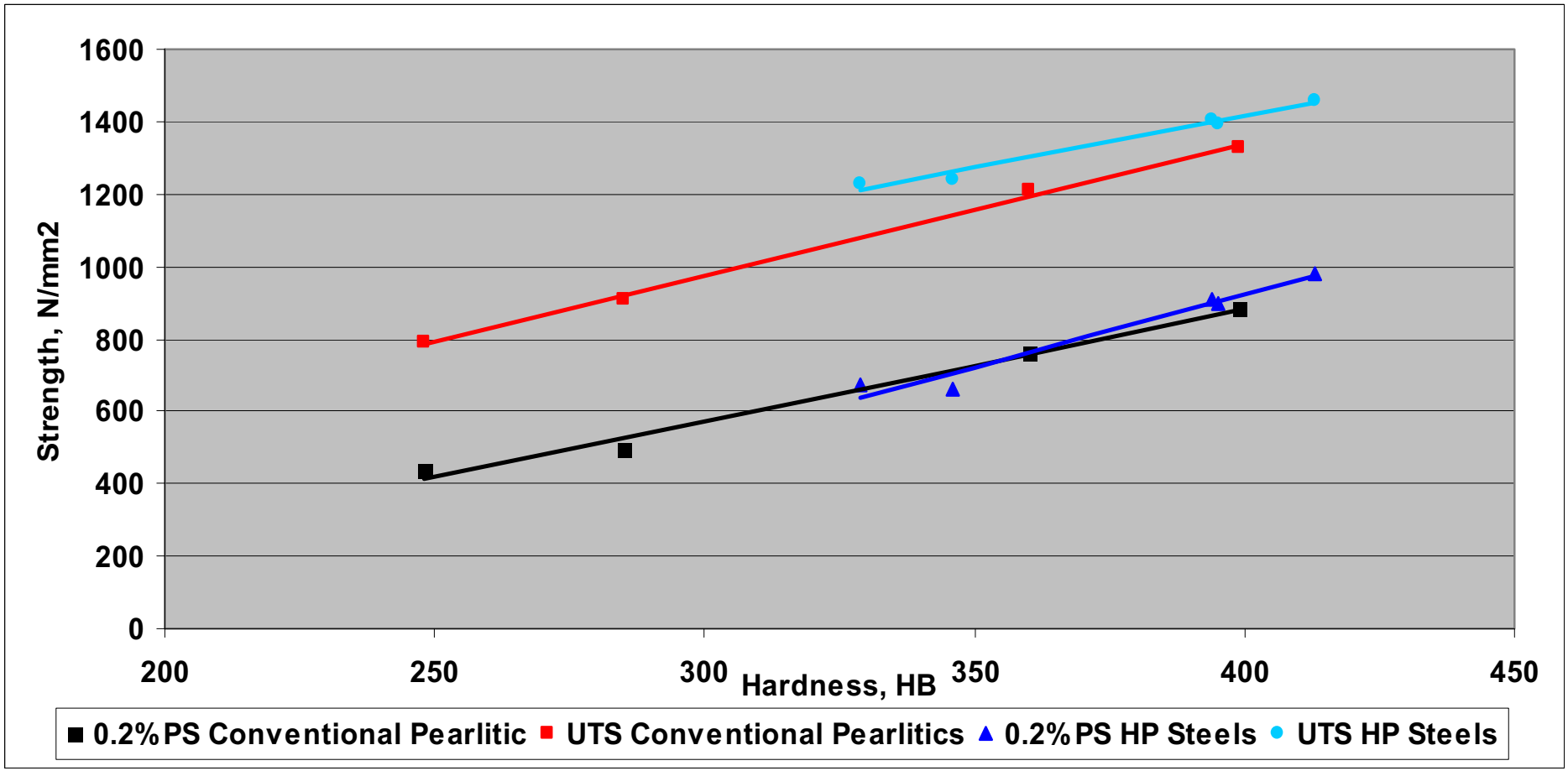
- ***up 120m long in as-rolled (216m LWR)***
- ***36m in heat treated condition (216 LWR)***



Fine Pearlitic Microstructure of Corus HP as-rolled Steel

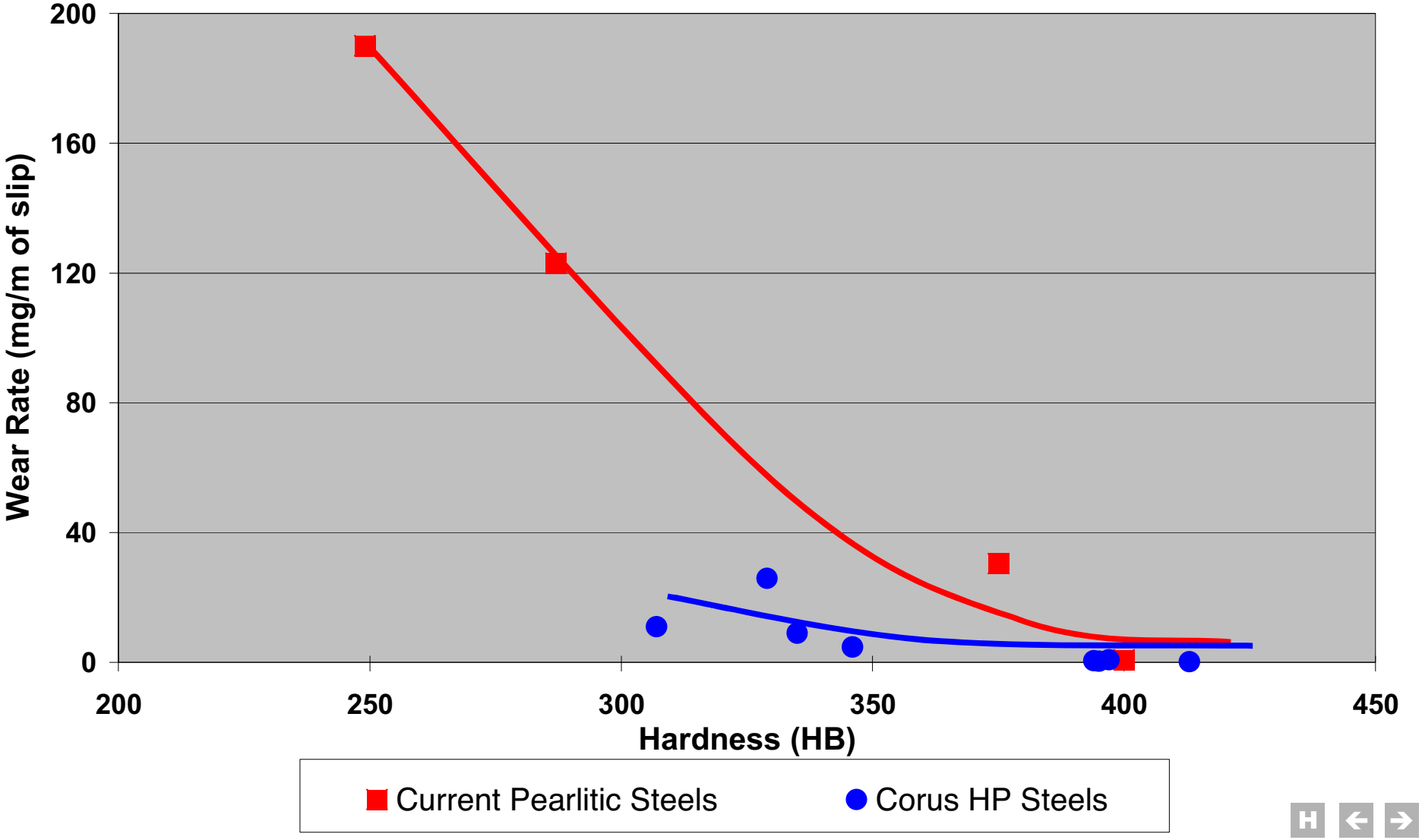
Corus HP Steel – Tensile Properties

much more than rail



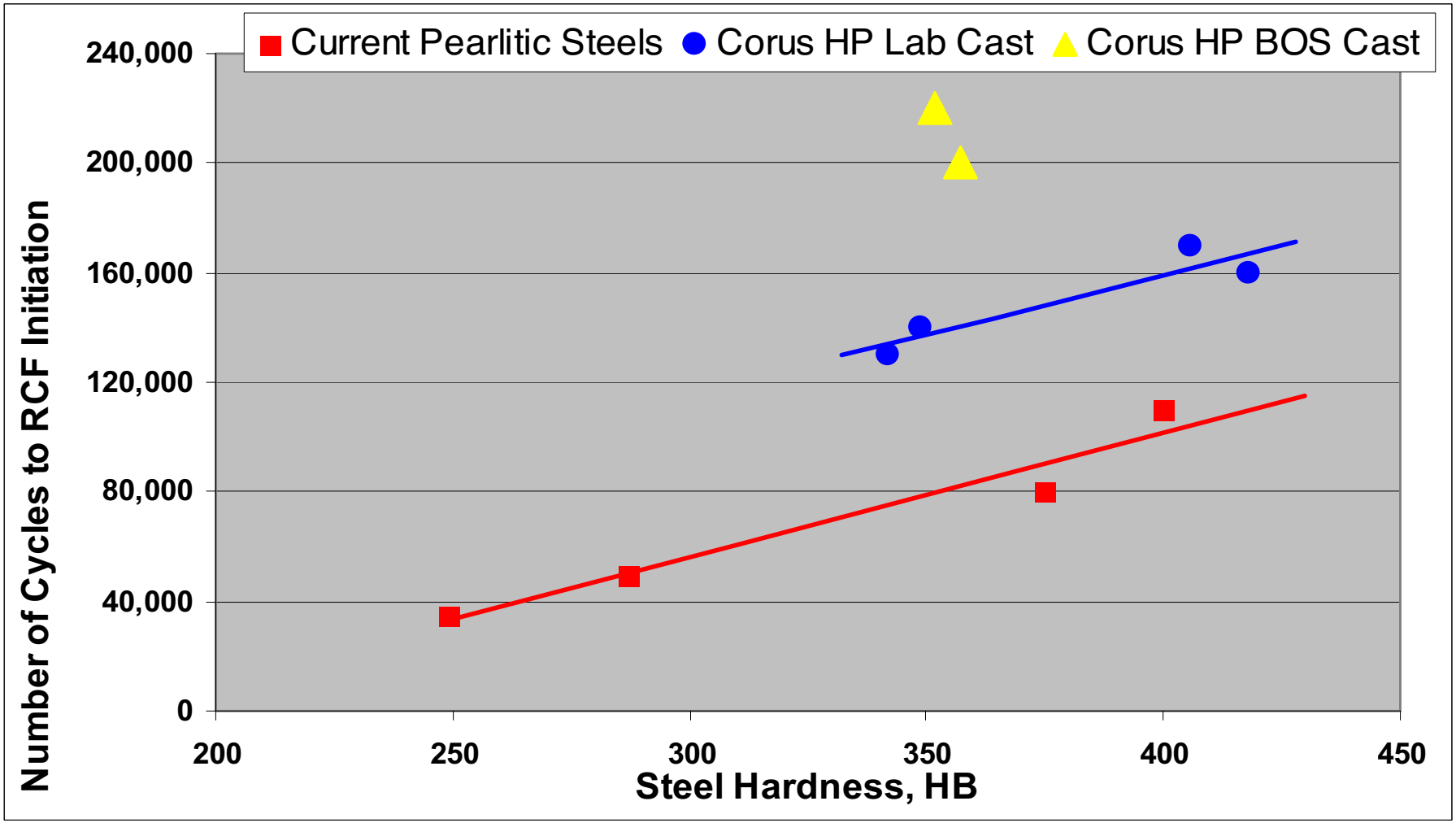
Corus HP Steel – RCF Resistance

much more than rail



Corus HP Steel – RCF Resistance

much more than rail



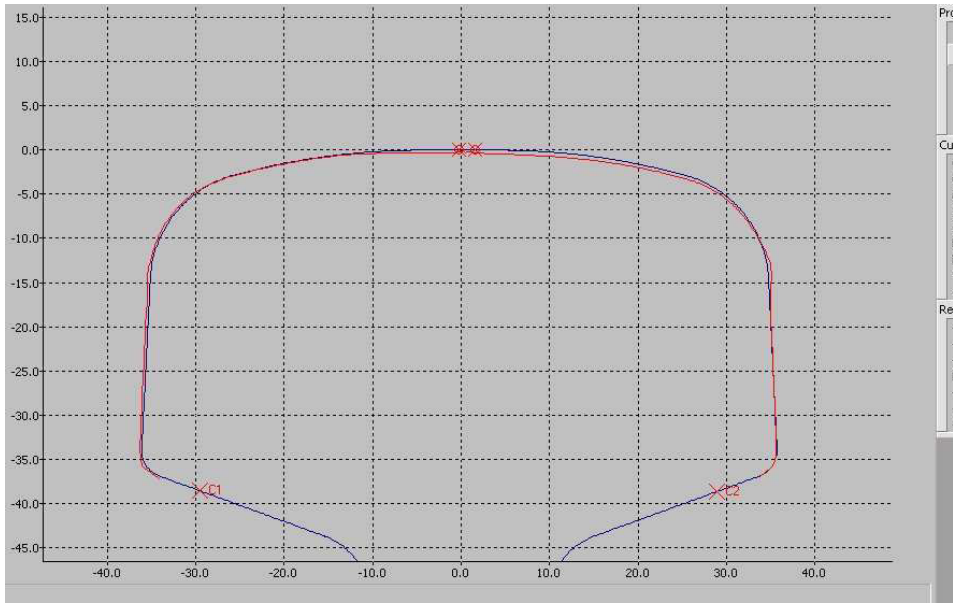
Rail property comparisons

much more than rail

Property		R260	350HT	400 MHH	Corus HP (As Rolled)	Corus HP (Heat Treated)
Crown Hardness (HB)		284 – 290; Consistent throughout section	350 – 390	388 – 401	**340 – 350 Consistent throughout section**	**R/S 415 – 445 Crown 399 – 416; 30mm depth: 375 – 388**
0.2% Proof Strength (MPa)		470 – 510	700 – 850	830 – 850	**649 – 678**	**1003 – 1012**
UTS (MPa)		979 – 998	1100 – 1250	1296 – 1357	**1175 – 1216**	**1444 – 1445**
Elongation (%)		10 – 12	12	12 – 13	**7 – 10**	**11 – 12**
Fracture Toughness (MPa.m$^{1/2)}$		32 – 36	33 – 39	33 – 44	**31.5 – 32.5**	**32**
Fatigue Strength, MPa		336			**479**	
Fatigue Crack Growth Rate (m/G.cycles)	DK = 10	8.6 – 10.4	9,6	4.8 – 17	**9,8**	**9,6**
	DK =13.5	22.6 – 33.4	22,5	19.6 – 31.0	**37**	**24,6**
Wear Rate (mg/m of slip)		124	30,5	0,8	**3,6**	**0,5**
RCF resistance (No of cycles to observed crack initiation)		50 000	80 000	110 000	**200,000 – 220,000**	**170 000**
Foot residual stress (MPa)		167 – 219	2 – 36	6 – 52	**180 – 254**	**24 – 41**

Corus HP Steel – in track assessment

much more than rail



56E1 Rails from trials installed in Scunthorpe steel works track

Radius 140m

Axle load: 50t

Low speed

Traffic carried – ~15 MGT

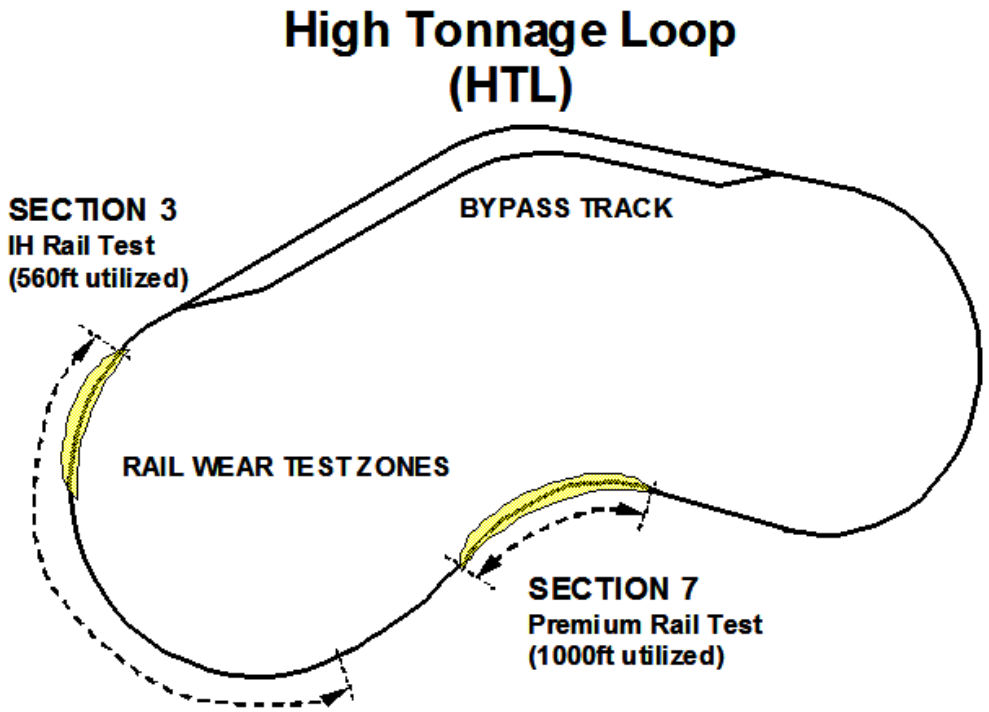
tiny amount of wear on gauge corner as rail adjusts to wheels
no RCF

Facility for Accelerated Service Testing - High Tonnage Loop

much more than rail

Section 3 :

5° reverse curve
no lubrification on HR/LR
20 # grades at about 400HB
Corus HP heat treated



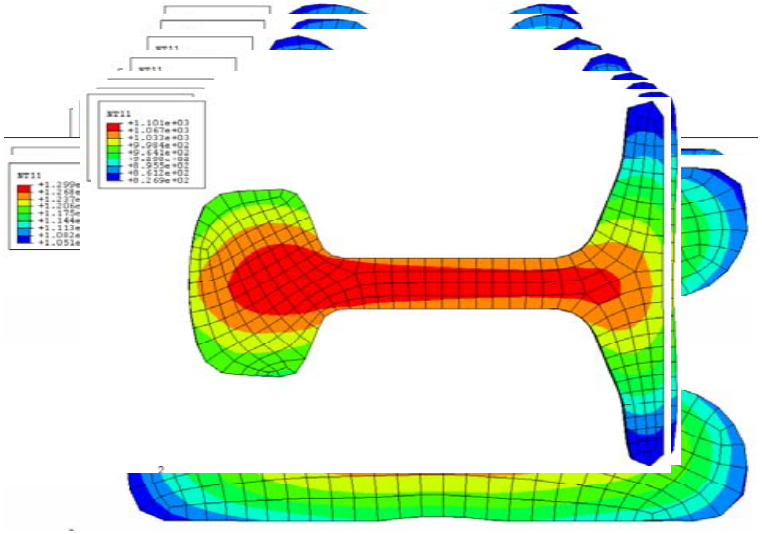
Trains :

39T/axle
40 mph
1.0 – 1.3 MGT/night
100 – 125 MGT/year

Section 7 :

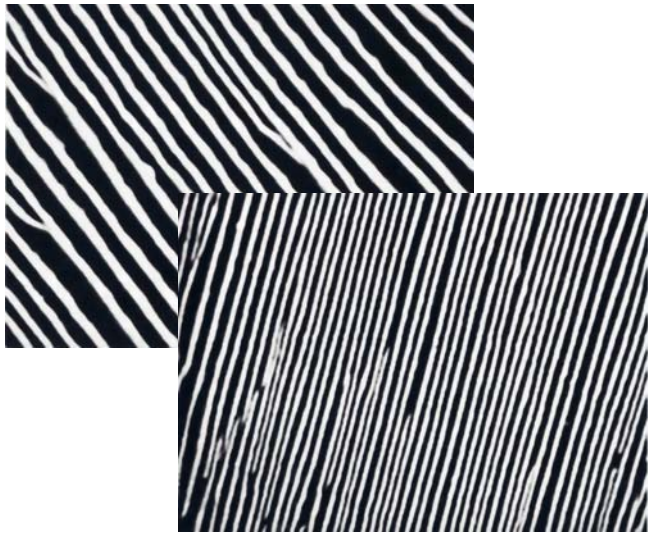
5° reverse curve
lubrification on HR
5 # grades at about 330 HB
Corus HP as rolled

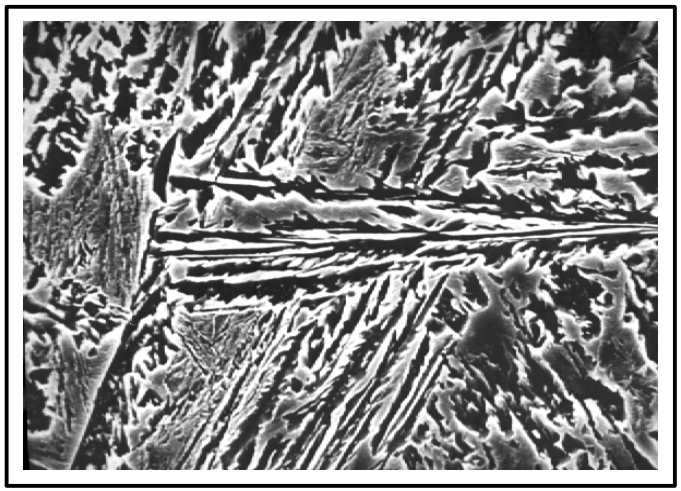
- 3 Commercial casts (~900t) made to date
  - Material behaviour during rolling and straightening different to Grade 260 – hence operating parameters have had to be developed
- Several 56E1 rails now available for installation
- Sufficient blooms for up to 50 X 108m rails of 56E1/60E2
- Rollings undertaken/planned in
  - 56E1
  - 60E2
  - 95RBH
  - 60E1A1
  - 39E1
- Further casts of HP steel planned



Bainitic grades – metallurgical background

- Lamellar mixture of soft ferrite (a) and hard iron carbide (Fe3C)
- The very hard iron carbide confers good rolling contact resistance but results in poor ductility and toughness
- Limited scope for further improvement



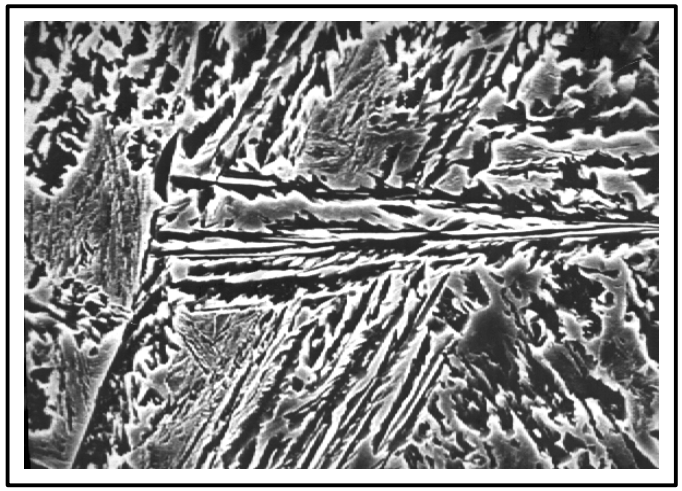


- Low C base - more ductile and readily weldable steel
- Radically different microstructure
- Embrittling carbide phase replaced with soft and ductile austenite
- As-rolled, i.e. no heat treatment required

Potential Benefits of Bainitic Rails

Rail Property Improvement

- Dramatically improved resistance to surface cracking by fatigue and rail wear
- Considerably tougher and more ductile than existing rails
- Considerably higher proof stress
- Potential benefits for reduced wheel wear

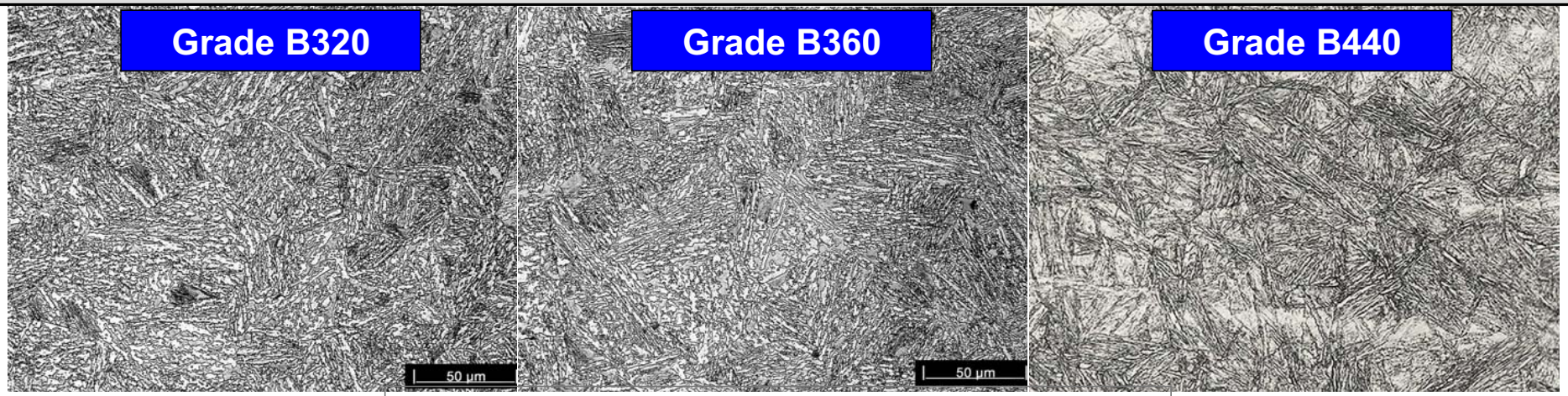


Technical Advantages to the Customer

Greatly enhanced rail life/ less frequent rail grinding

Lower incidence of rail fractures/reduced track maintenance costs

More corrugation resistant/less frequent rail grinding



Increasing Hardness of Bainitic Grades

Bainitic Rail Steels

Conventional bainitic structure – Ferrite and Carbide

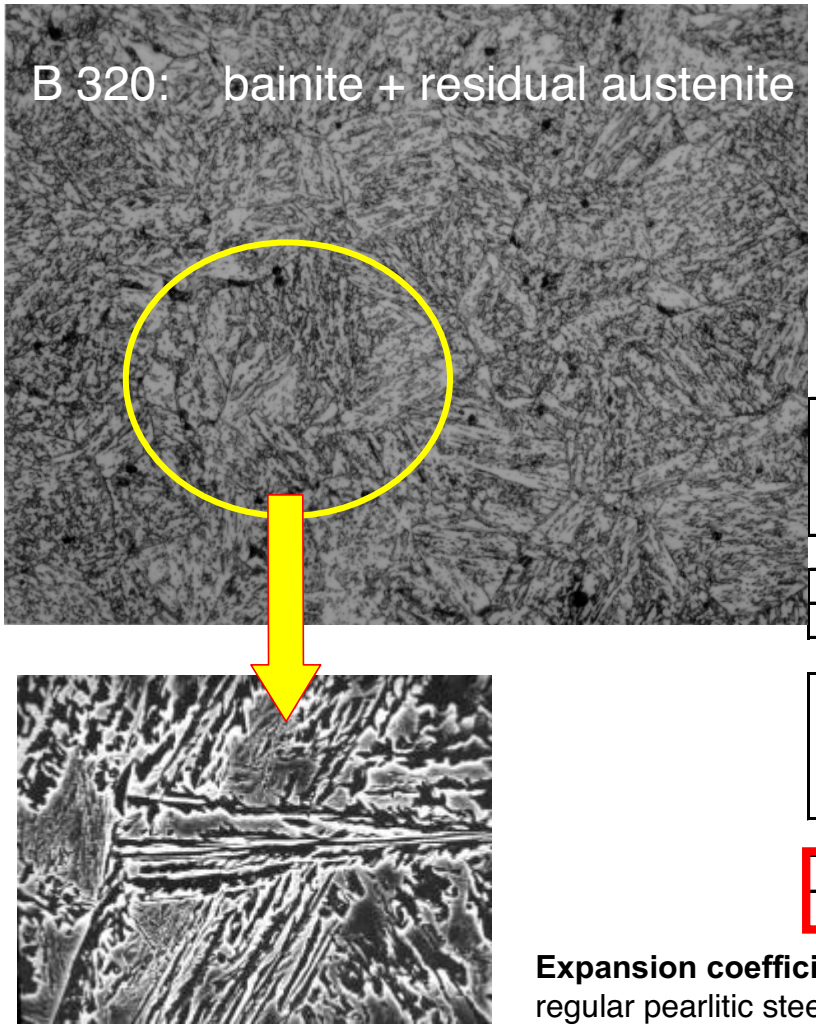
Have been tried in the past but offered no real advantages

Low-carbon carbide free structure – Ferrite and Austenite

Susceptibility to Stress Corrosion Cracking, managed by control of composition & residual stresses

Corus bainitic grades

much more than rail



- **Low Carbon base, more ductile and readily weldable steel**
- **Radically different microstructure: embrittling carbide phase replaced with soft and ductile austenite**
- **As-rolled, i.e. no heat treatment required**

Grade	Chemistry % mass					
	C	Si	Mn	Cr	V	Mo
B320	0.15/0.25	1.00/1.50	1.40/1.70	0.30/0.70	0.10/0.20	0.10/0.20
B360	0.25/0.35	1.00/1.50	1.40/1.70	0.30/0.70	0.03 max	0.10/0.20

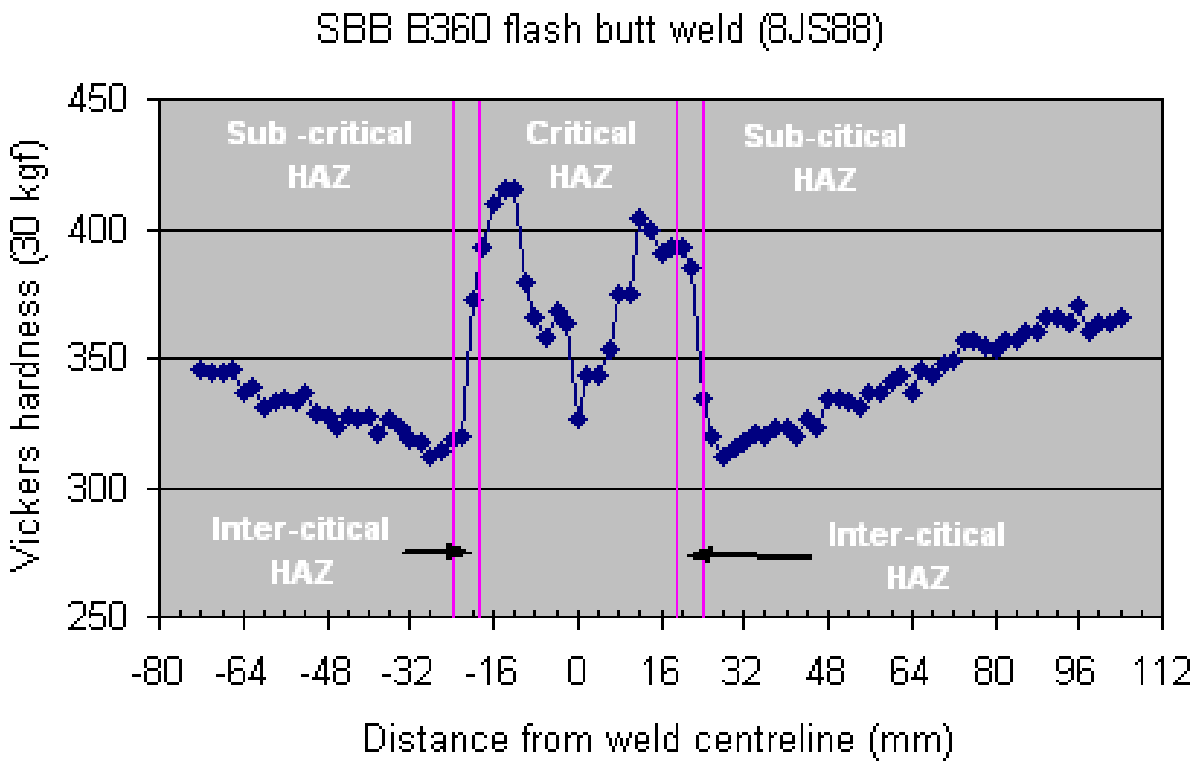
Grade	•Mechanical characteristics on new rails					
	TS N/mm•²	YS N/mm•²	E %	RA %	Hardness (HB) centre running surface	Impact (-20°C) J/cm²
B320	**1100/1200**	**800/950**	**14/17**	**35/50**	**320/340**	**90/120**
B360	**1200/1300**	**850/1000**	**13/16**	**30/45**	**360/390**	**60/120**

Expansion coefficient: 11,8.10^{-6} m/m°C at 20°C and 12,2.10^{-6} at 60°C (10.5. 10^{-6} for the regular pearlitic steels)

Resistivity: 39 $\mu\Omega$.cm (25 for the 900A and 28 for the MHH)

FBW results B360-B360

much more than rail



- bainite and retained austenite in the critical HAZ
- complexe structures(ferrite/martensite/bainite/austenite) in the inter-critical zones
- tempered bainite in the sub-critical zones

Corus bainitic steels tests

much more than rail

Completed :

- SNCF Dieupentale : B320 <-> R260 head checks

In progress:

- SNCF Vaux en Pré : B360 <-> R260 movable points
- SNCF Pantin : B360 <-> R260 switch blades
- Eurotunnel (tunnel) : B320 <-> R260
- SBB : B360 <-> R350HT

Example of bainitic B360 tests – movable points

much more than rail

LGV Sud-Est Paris-Lyon
2 switches at 270 and 300 km/h layed in june 2005

17 T/axle
30 000 T/day

60E1A4 machined and forged to 60E1

Example of bainitic B360 tests – movable points

much more than rail

R260 : head checks developping into spalling, on a part of the rail

Example of bainitic B360 tests – movable points

much more than rail

Bainitic B360 : very light wear

Bainitic B360 : no surface defects

B360 – SNCF Pantin – switch blade – head check

much more than rail

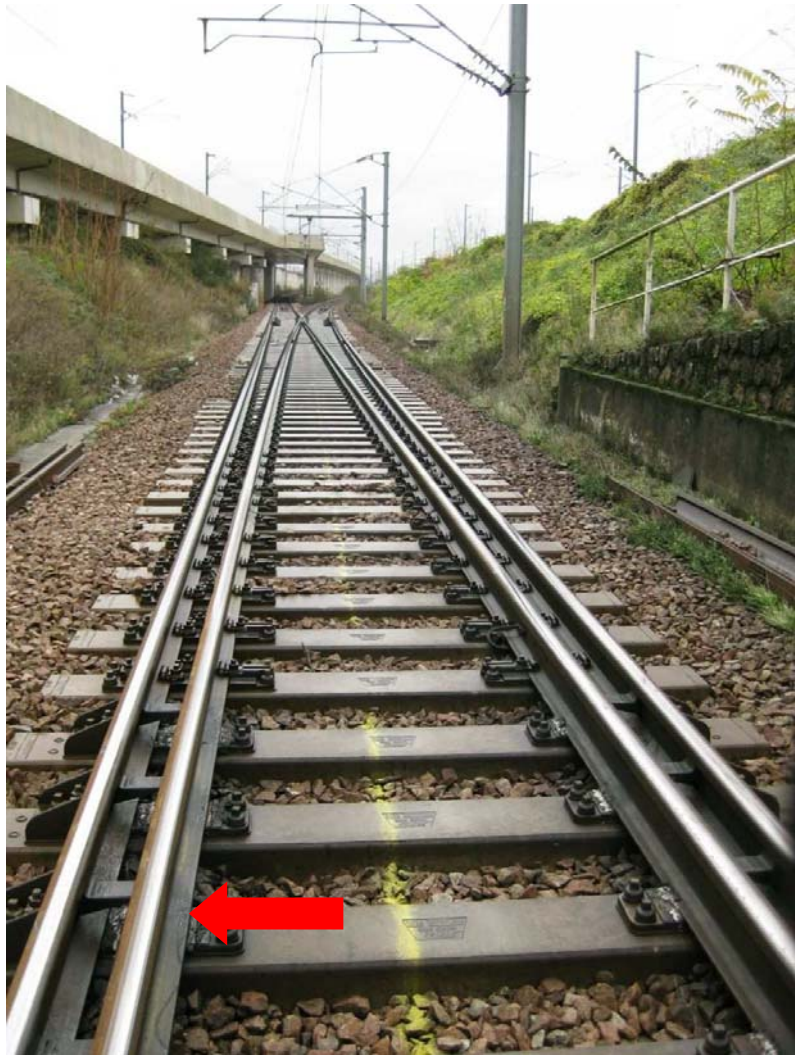
Line Paris – Mulhouse

Passengers trains

120 km/h

up to 20 T/axle
42 000 T/day

Profile 60E1T2



B360 – SNCF Pantin – switch blade – head check

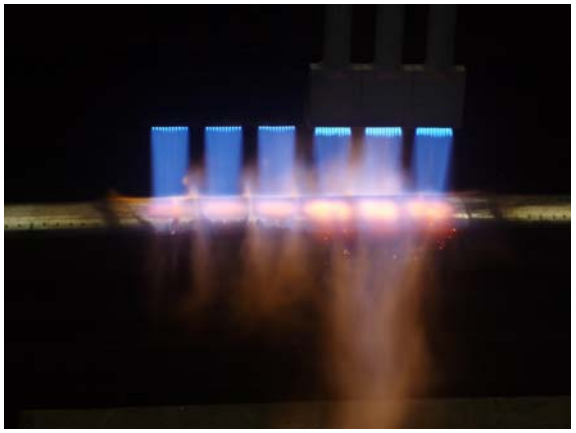
much more than rail

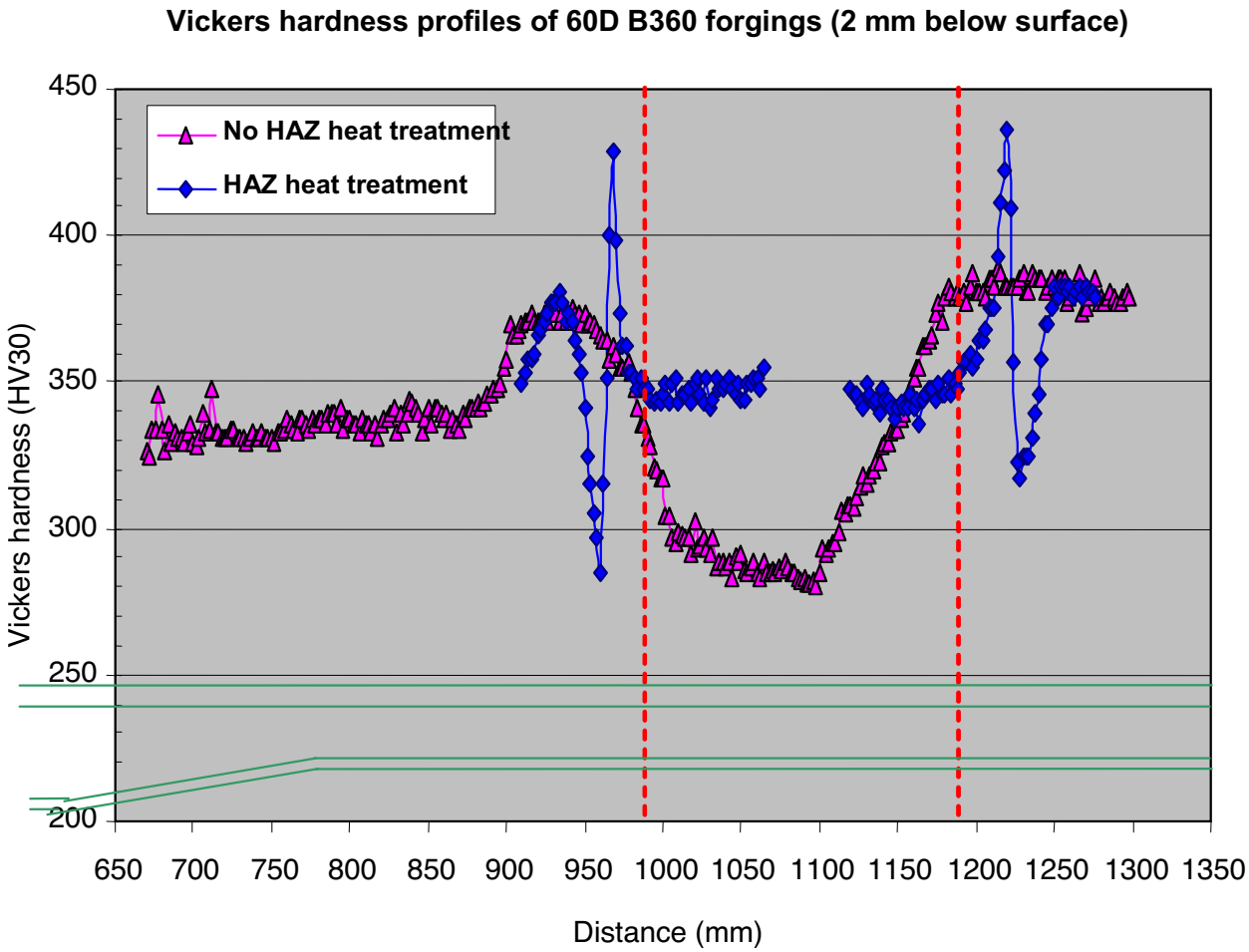
Grade R260 : very soon head check, require close survey of the area

Bainitic B360 : no head check at 24MGT

Forging procedure under validation (movable points,S&C)

much more than rail





Example of bainitic B320 tests – Eurotunnel

much more than rail

Calais Folkestone

Grade: B 320 (60E1)

Curve: R 4230 m

Mixed trafic : up to 22.5T/axle
passengers 160kph
freight 140 kph

Installation: mid January 2007

Load: 100 MGT/y

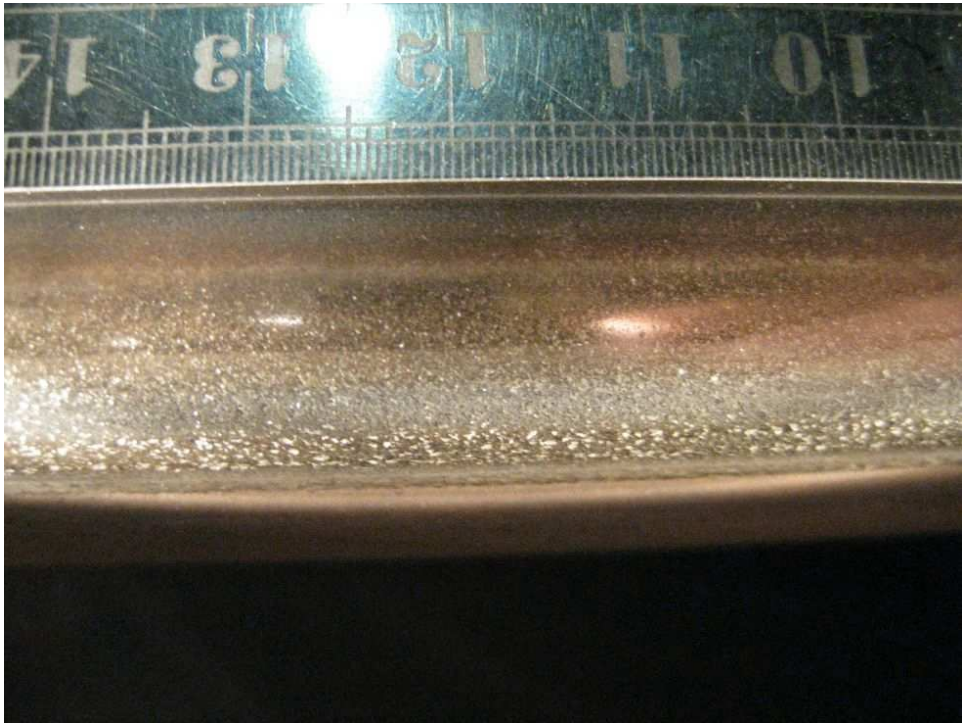
Current issue: RCF and internal fatigue

Target: life expectancy +30%

Trials supported by the competitivess cluster I-Trans partnership with Eurotunnel, Railtech and Ecole des Mines

Example of bainitic B320 tests – Eurotunnel

much more than rail



After 240 MGT

B320 no head check, or very shallow

(no grinding required)

R260 many head check

(except on the test area, grinding every 6 monthes – 50MGT)

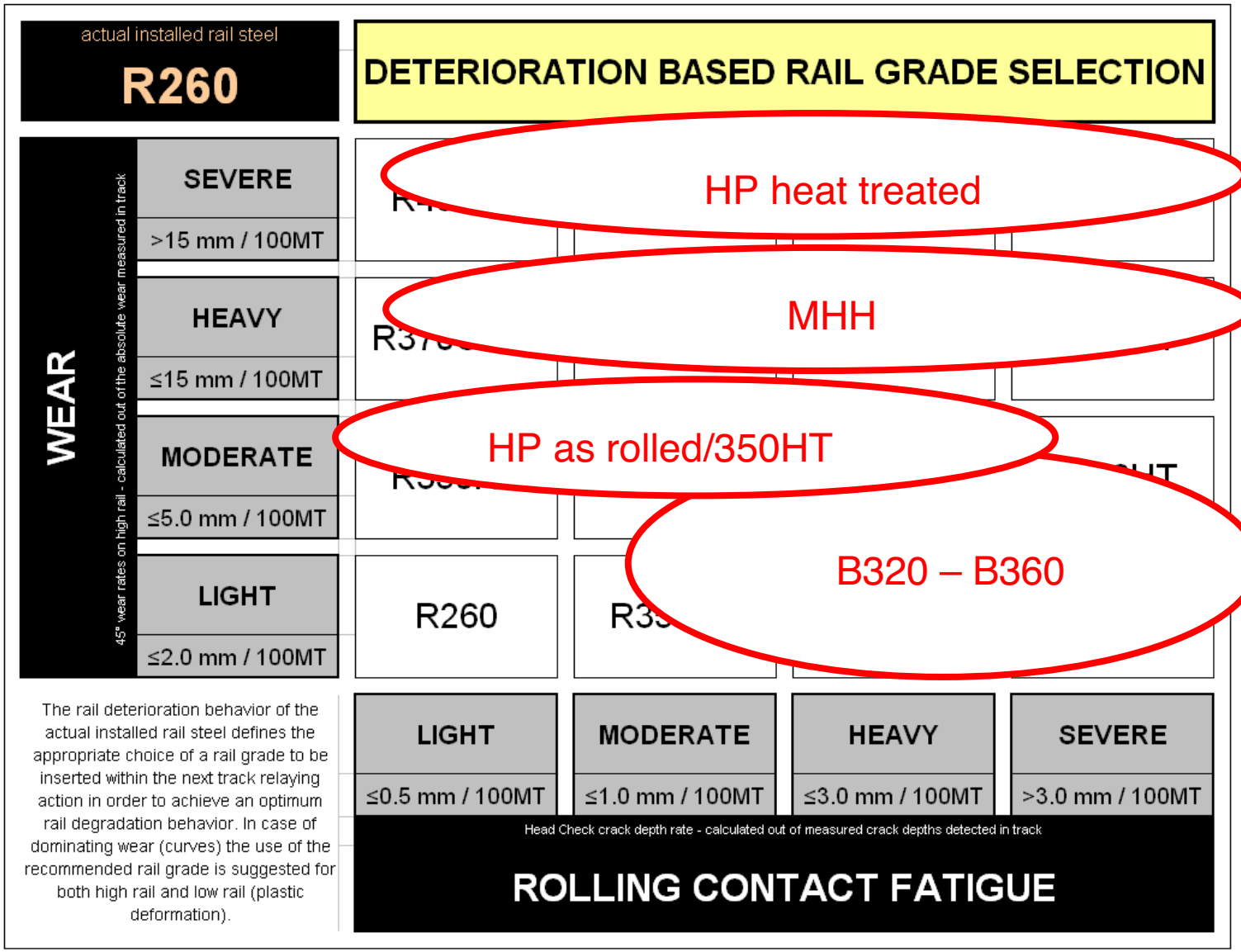
Low carbon bainitic steels show very good results on track against head-checks

physical properties (resistivity, expansion coefficient) and welding behviour have been adressed

a tight survey of the straightening conditions is necessary to control the residual stresses in the foot.

First applications :

SNCF for movable points
SBB for plain track against HC


actual installed rail steel
R260
DETERIORATION BASED RAIL GRADE SELECTION
WEAR
45° wear rates on high rail - calculated out of the absolute wear measured in track
SEVERE
>15 mm / 100MT
HEAVY
≤15 mm / 100MT
MODERATE
≤5.0 mm / 100MT
LIGHT
≤2.0 mm / 100MT
R260
HP heat treated
MHH
HP as rolled/350HT
B320 – B360
The rail deterioration behavior of the actual installed rail steel defines the appropriate choice of a rail grade to be inserted within the next track relaying action in order to achieve an optimum rail degradation behavior. In case of dominating wear (curves) the use of the recommended rail grade is suggested for both high rail and low rail (plastic deformation).
LIGHT
≤0.5 mm / 100MT
MODERATE
≤1.0 mm / 100MT
HEAVY
≤3.0 mm / 100MT
SEVERE
>3.0 mm / 100MT
Head Check crack depth rate - calculated out of measured crack depths detected in track
ROLLING CONTACT FATIGUE

Corus - Rail Sector

much more than rail

Corus serves the rail industry through offering;

Rail and related products and **railway infrastructure services**

***Corus** seeks*

partnerships

with clients and other businesses to ensure it stays at the cutting edge of the industry.

Corus

expertise,

developed over **125 years** of manufacturing and metallurgy, provides the foundation of our authority in railway products.

A focus on

quality

has enabled **Corus** to operate successfully in the rail industry for over a century.

Constantly

innovating

Corus has been a pioneer in the rail industry:
Steel sleepers,
Silent Track,
Sogenox,
first company in Europe to manufacture rail for high speed lines,
first company to adopt technology that measures rail straightness.

Key Facts

much more than rail

The businesses employ over **2,000** people across the UK and France and has access to the knowledge and experience of the **Corus** group's **40,000** staff

The majority of work comes from the **UK** & **France**

From Scunthorpe and Hayange mills supplying the main railways networks in Europe and al over the world

Output of rails production about **550 000 tons** per year

The **Rail Products** business accounts for **70%** of business turnover

& **Railway Infrastructure services** the remaining **30%**


corus
Thank you for your attention
TGV V150
574.8 Km/h
corus
High Speed Rail Record
www.muchmorethanrail.com/muchmore