



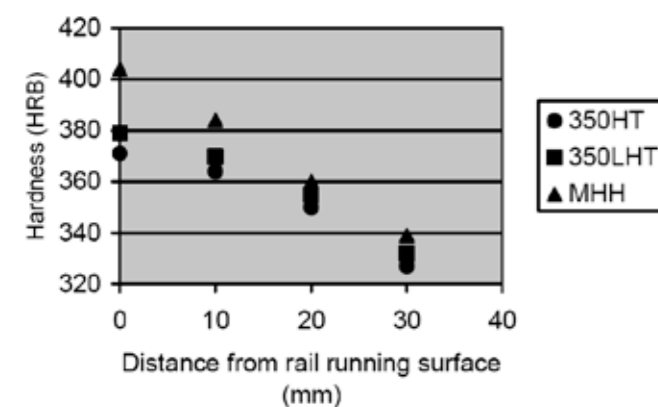
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## Heat Treated Rails

In order to be able to compare more easily the hardness profiles of the different grades, typical values of Corus are given in the graph below:



It is clear that the MHH grade gives a much higher surface hardness.

The Corus heat treatment results in high in-depth hardnesses, which even under high axle loads prevents plastic deformation and reduces wear.

### Residual stresses

The heat treatment carried out at Corus does not require roller straightening after treatment; this means that the Corus products described here have extremely low residual stresses in their supply condition. Transverse residual stresses are negative in head, web and foot, which results in a stress state that limits the propagation of cracks. The table below shows comparative values:

Conditions	Longitudinal stresses (MPa) measured by strain gauges			Saw cut test (mm)	
	Head	Web	Foot		
Standard grade	Natural cooling before straightening	30	-20	30	+0.2
	Natural cooling after straightening	140/180	-110/-160	190/220	+1.5/+1.8
Conventional Heat treatment	In line heat treatment before straightening	-140	150	64	-1.6
	In line heat treatment after straightening	270	-160	330	+2.8
Corus Heat treatment	Off line heat treatment without roller straightening	<b>-86</b>	<b>+41</b>	<b>-30</b>	<b>-1.5</b>

### Weldability

Grades R350HT, R350LHT and MHH can be welded by normal aluminothermic and flash butt welding procedures. In the case of aluminothermic welding the welding portion should be adapted to the hardness of the rail to ensure a good mechanical continuity between the weld and the rail.

As grades R50LHT and MHH are alloyed with chromium to increase their hardenability, these grades should never be post-cooled after welding, as this could lead to undesirable martensite formation in the weld.

### Conclusion

Corus supplies heat-treated products that deliver increased safety for the rail network, due to their beneficial residual stresses that limit the propagation of cracks. A variety of hardness levels is available, so that the right product can be chosen for the right purpose. A large tonnage has been supplied to railways throughout the world giving the expected high in-service performance.

Corus' MHH product is ideally suited for the most strenuous applications, limiting wear and rolling contact fatigue under high axle loads, and thus being able to reduce maintenance costs.

### Approval

EBA-approval (German Federal Railway Authority) for test installation reference number has been granted on 24.1.2008 under reference number 21.61.Jozb (556/05).

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## Heat Treated Rails

Growth in railway traffic, greater axle loads, higher speeds and the introduction of new generations of rolling stock have increased the magnitude and complexity of stresses within the wheel-rail contact, particularly in moderate and tight curves.



Under normal conditions, wear resistance of steels increases with hardness and is governed by the content of carbon and other alloying elements, as well as the pearlitic interlamellar spacing in the steel. Hardness can be improved by heat treatment, and Corus has played an active role in the refinement of steel manufacturing processes and the development of heat-treated grades. Field tests and laboratory analysis have shown a range of performance benefits associated with Corus MHH rails, that address the primary rail degradation mechanisms of rolling contact fatigue, vertical and side wear, and loss of rail head shape through plastic deformation. Furthermore, improvements in steel manufacture and the deployment of modern in-line NDT techniques has led to the elimination of internal fatigue from internal flaws. These qualities deliver the following improvements:

- Reduced incidence of rail failures
- Longer in-service rail life
- Reduced Life Cycle Costs (LCC) for renewal and maintenance

### Steady processes produce consistent rail properties

Corus installed their improved patented heat treatment plant in 1994 and has been producing up to 60kt per year since that time with the total supplied to railways worldwide exceeding 750,000 tonnes.

### Heating the whole section by induction

A key requirement for any heat treatment process is precise control of the parameters that give consistent properties in the product. At Corus, energy input and rail speed are accurately controlled to ensure a precision heat-treatment process that is consistent along the full length of every rail. Exit temperatures are continuously monitored in the head and the foot to confirm product consistency.

The whole rail section is heated to above the austenitic transformation temperature using induction heating. This provides a carefully balanced temperature profile across the section, ready for controlled cooling.

### Air cooling of the whole head

The reheated rail is cooled in an air cooling unit following re-austenitisation. The critical cooling parameters include the air pressures, air flows and the configuration and distance between the nozzles and the rail head. The combination of precision heating and controlled cooling provides a consistent ultrafine pearlitic structure **and a finer grain size than that achieved with in-line heat treatment processes.** The benefits of fine interlamellar spacing and reduced austenite grain and pearlite nodule size are well established and acknowledged and in the case of the Corus Heat-treated products, this structure is found around the full rail head surface and extends deep into the head to provide through-life wear resistance.

### R350HT, R350LHT and MHH grades

Three main heat-treated products are available: R350HT and R350LHT, both made to the EN13674-1:2003 standard, and the MHH product, made to the AREMA (American) standard plus a Corus Rail specification.



### Straightness and optimised stresses

Finite element modelling has been carried out to ensure that the process produces not only the desired metallurgical properties but also a straight almost stress-free product. Conventionally heat-treated rails require subsequent roller straightening; moreover, they generally have higher yield strength than standard grade rails, and so develop higher residual stresses during the straightening process. Corus's heat-treated rails do not require roller straightening after heat treatment and so the favourable heat treatment stresses are retained. This is a major advantage since the significantly lower longitudinal stresses in the foot eliminate the risk of fatigue failures from the corrosion pits in normal track conditions.

### Chemical composition

The R350HT product is a heat-treated version of the R260 grade (or 900A grade along UIC860.O), whereas the R350LHT and MHH are both heat-treated microalloyed grades. For the microalloyed grades, a small chromium addition is used to increase the hardenability of these grades. Composition (in weight %) and hardness ranges are given in the table below:

Chemical Composition	C	Si	Mn	P	S	Cr	Al	V	N	Hardness Range (HBW)
R350HT	Min	0.70	0.13	0.65		0.008				350-390
	Max	0.82	0.60	1.25	0.025	0.030	0.15	0.004	0.030	
R350LHT	Min	0.70	0.13	0.65		0.008				350-390
	Max	0.82	0.60	1.25	0.025	0.030	0.30	0.004	0.030	
MHH	Min	0.72	0.40	0.80			0.40			381-408
	Max	0.82	0.80	1.10	0.020	0.020	0.60	0.004	0.030	



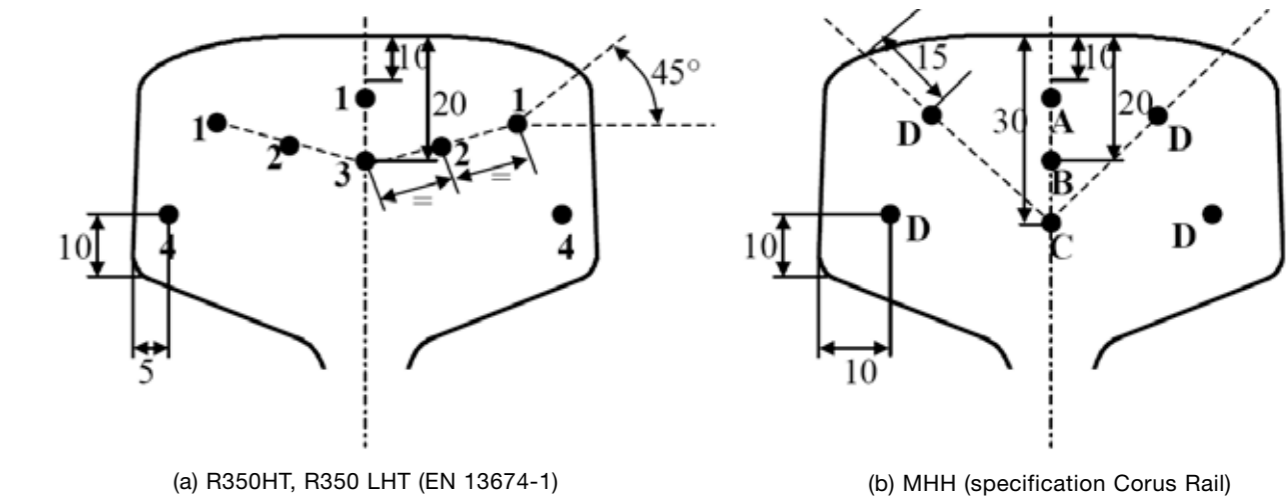
### Mechanical properties

The minimum mechanical properties, as stated in the various specifications, are:

Mechanical properties	Min. Yield Strength 0.2 (MPa)	Min. Tensile Strength (MPa)	Min. Elongation (%)	Min. Reduction of Area (%)
R350HT		1175	9	
R350LHT		1175	9	
MHH	830	1280	12	35

Figure 1

Hardness testing positions, all distances in mm.



The different specifications use different hardness maps to establish the hardness within the profile; the two maps are shown in figure 1, with the hardness (in HBW) required at each position given below:

Mechanical properties	1	2	3	4	A	B	C
R350HT	340	331	321	340			
R350LHT	340	331	321	340			
MHH					357	346	326