
DB Netz has extended the application range for R350HT rail in curves from a maximum radius of 700 m to 1 500 m for intensively-used track.

Managing rail life to match performance and cut costs

STEELS With higher traffic volumes, axleloads and speeds imposing greater demands on modern track, the Innotrack study has confirmed that using high-quality rail steels in combination with an optimised grinding regime improves performance, cost-effectiveness and availability.

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Continuing pressure to improve railway productivity has seen steady increases in axleloads, train speeds and service frequencies. The result has been higher loadings applied to the rail-wheel system, and higher degradation of track components, as well as increased rail and wheel wear.

Around half a century ago, the first response was to demand more wear-resistant rail and wheel steels, leading to widespread use of R260 (S900A) carbon rail steels which offered greater wear resistance than the traditional R200 (S700) grade. At the same time, larger rail profiles such as 60 kg/m replaced the smaller 49 and 54 kg/m, particularly on main lines, and rail grinding was introduced to reduce dynamic forces by removing surface irregularities such as corrugation.

Over the past decade the steady increase in train speeds and traction power at the wheel-rail contact patch triggered growing problems of rolling contact fatigue which had previously only been seen in heavy haul applications. Today RCF has become the biggest concern for most rail infrastructure managers and suppliers. The degradation mechanism, with various manifestations including head checks, spalling, flaking and squats, is now the main cost driver for rail maintenance and renewals (Fig 1). But maximising the availability of infrastructure and reducing life-cycle costs have also become priorities.

Numerous projects have confirmed the benefits of using high-strength rail steels, in terms of both RAMS (Reliability, Availability, Maintainability and Safety) and life-cycle cost. Extensive testing around the world has shown that grade R350HT head-hardened rail offers significantly improved resistance to wear and RCF, increasing service life and reducing the need for maintenance by a factor of three compared to grade R260[1,2]. Economic assessments suggest that life-cycle costs can be cut by up to 50%[3,4].

As a result, many railways have changed their policy on the use of rail steels. For example, DB Netz has extended the application range for R350HT rail in curves from a maximum radius of 700 m to 1 500 m for intensively-used track, or even to 3 000 m where RCF is the main problem (RG 4.10 p35).

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The most impressive proof of this ongoing technological change can be found in the results of the EU-funded Innotrack research project (RG 1.10 p48). This brought together 35 partners from European rail infrastructure managers and their suppliers for 3½ years to study ways of reducing life-cycle costs and improving RAMS through the use of innovative track components, maintenance procedures and supporting logistics.

As in other studies, Innotrack undertook a comprehensive analysis of requirements and investigated the root causes of the current high cost of track maintenance and renewal. This led to new recommendations for selecting appropriate rail steel grades on the basis of curve radii and traffic tonnages (Fig 2). These are based on the results of more than 200 track tests as well as practical experience from various railways. The lower rate of degradation of heat-treated pearlitic rail grades has led to a general recommendation for the use of heat-treated rail grades for intensively-used tracks with radii up to 5 000 m.

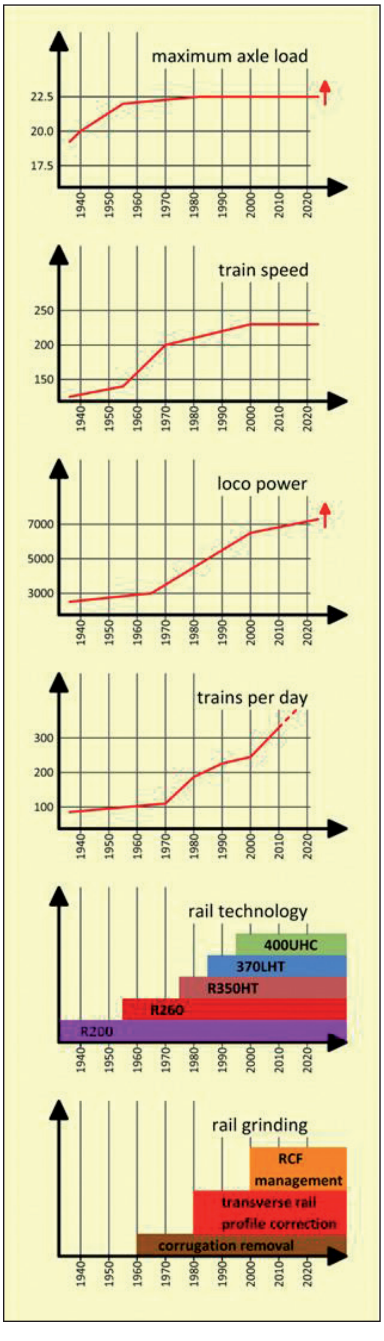
Learning from heavy haul

The Innotrack recommendations also take into account the latest developments in heat-treated rail steels such as R370CrHT (370LHT) and R400HT (400UHC), which have been included in the revised European standard prEN13674:2009. These rails are predominantly used by heavy haul railways, and have demonstrated excellent performance over several years under severe conditions.

Norway's Ofotbanan has been using grade 370LHT with 30 tonne axleloads for more than five years, replacing both standard grade S1200 and grade R350LHT rail. Observations have confirmed that the 370LHT rail shows less wear and fewer RCF defects than the R350LHT. The new rail steels have been combined with a new welding technique[5] and preventive maintenance strategy to produce a significant increase in service life and savings in life-cycle costs. Recent comparisons of 370LHT and R350HT rail undertaken on the east coast of Australia on a route which carries both coal trains with a 25 tonne axleload and conventional mixed traffic, have shown similar results.

Heavy haul railways in the USA, Brazil and Australia, which have axleloads up to 40 tonnes, are increasingly using hyper-eutectoid rails with a minimum Brinell hardness of 400 BHN, combined in most cases with a preventive grinding strategy. Tests to evaluate these hyper-eutectoid rail steels have confirmed their excellent performance[6].

Today's mixed-traffic railways face the same basic challenges and requirements as heavy haul operators,



Left: Fig 1. As axle loads, speeds and power at rail have increased over the years, new rail steels and grinding techniques have been adopted.

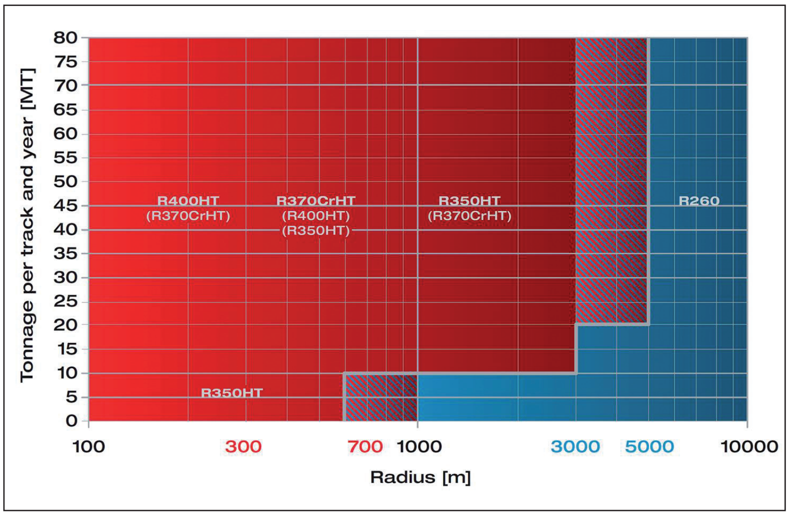


Fig 2. Appropriate rail steel grades can be selected according to curve radii.

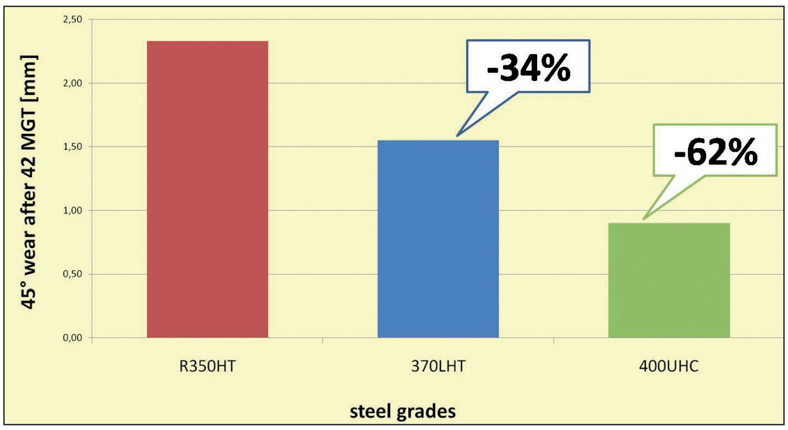


Fig 3. The results of recent wear resistance tests on a mixed-traffic line in Austria.

in terms of maximising availability, increasing productivity and operating efficiently with lower costs. So it is appropriate to consider using the same high-strength rail steels.

Fig 3 shows the results of recent wear resistance tests on a mixed-traffic line in Austria. After a relatively short period (a total of 42 million gross tonnes) the three rail grades show significant differences in wear resistance. The 400UHC rail showed a reduction in gauge corner wear of 62% compared to R350HT while the 370LHT offered an improvement of 34%. On the basis of earlier tests, the differences should increase further as the loading rises. It is notable that this test does not include R260 rail, even as a reference point. Past trials on the same curves found that the wear rate of R260 rail was three times that recorded with the R350HT grade.

Fig 4 shows the RCF resistance of the three rail types. The performance of 370LHT and 400UHC rail suggests that the higher the steel grade, the later the first appearance of head checks and — more importantly — the lower the rate of degradation caused by crack growth. These trials have also shown a significant improvement in the resistance of high-grade rail to the formation of corrugation.

Optimised grinding regime

Even the best rail cannot provide maximum performance without proper maintenance. But harder steel grades allow a more flexible and efficient maintenance regime, as their extremely low wear rate means they retain the target rail head profile for longer than softer grades. This reduces the need for frequent grinding to restore optimum contact conditions, helping to maximise line availability.

New rail profiles rarely provide an optimum contact profile for the majority of passing wheels, and improved wear resistance does not allow newly-installed high-grade rail to wear quickly enough towards the shape of the average worn wheel profile. As a result, the high rail in shallow curves is often characterised by a rather small and thus overloaded contact zone close to the gauge corner, encouraging the initiation of gauge-corner cracking.

Hence it has become current practice to modify gauge corner geometry with an initial grinding pass, removing some metal from the critical location to widen the contact area between wheel and rail and reduce contact forces. To achieve best results, high-performance rails should be ground as soon as possible after installation to optimise contact conditions and reduce the risk that RCF might develop before the next scheduled grinding cycle.

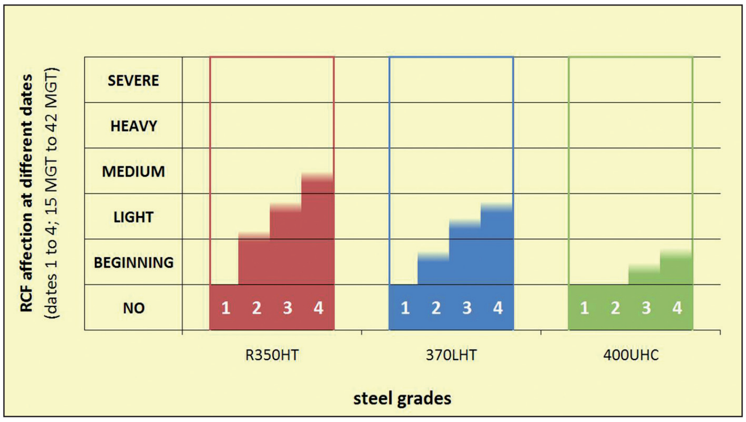


Fig 4. RCF resistance of three rail steel types. The performance of 370LHT and 400UHC rail suggests that the higher the steel grade, the later the first appearance of head checks and the lower the rate of degradation caused by crack growth.

Innotrack work package 4.5 developed grinding recommendations for rail subject to gauge-corner cracking[7]. The use of anti-head check profiles with a degree of gauge-corner undercutting has already become standard for some European infrastructure managers (Fig 5).

A successful preventive maintenance policy begins with the initial grinding of new rail to provide a specified target profile, or corrective grinding of rail which has been in service for some time and exhibits RCF, in order to remove the fatigued surface layer and restore the target profile. After that, preventive grinding should be undertaken on a regular cycle.

Each grinding pass removes the top surface layer, eliminating any small head checks before they can grow in an exponential way. The earlier the intervention, the less material needs to be removed and the quicker the work can be done. Ideally, grinding should be undertaken in a single pass to minimise disruption to train operations, so the degree of acceptable damage before intervention is limited by the metal removal rate, which in turn is determined by the grinding machine being used.

Based on the capabilities of current machines, Innotrack recommends a maximum removal rate of 0·6 mm at the gauge corner in parallel with up to 0·2 mm at the rail centre. These values need to be reviewed in the light of local track and traffic conditions and the machine capacity available. The better the performance of the rail steel, the lower the required metal removal rate and the longer the interval between grinding.

Ideally, rail grinding should be accompanied by simultaneous

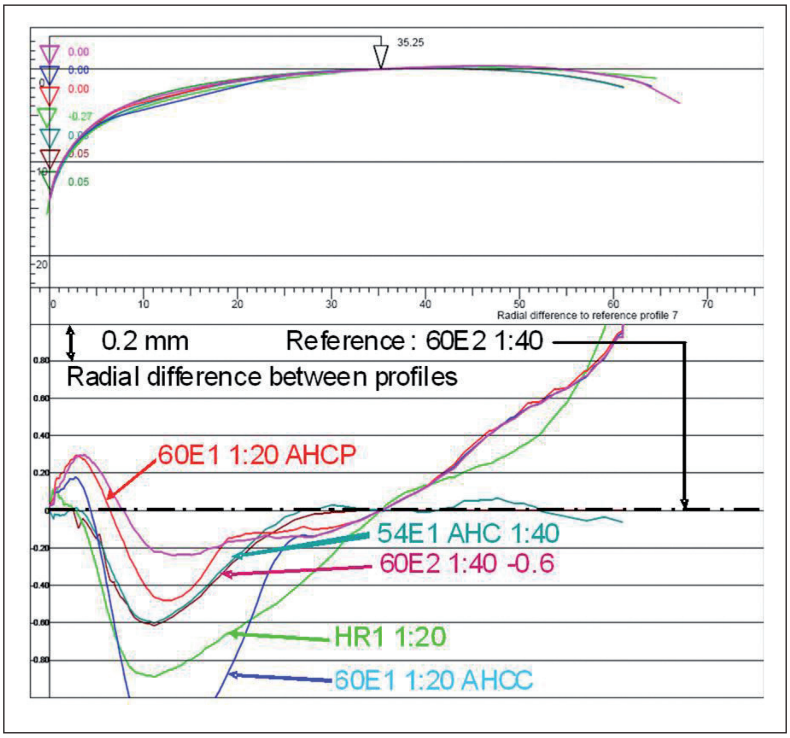


Fig 5. Several European infrastructure managers have adopted anti-head check profiles with a degree of gauge-corner undercutting.

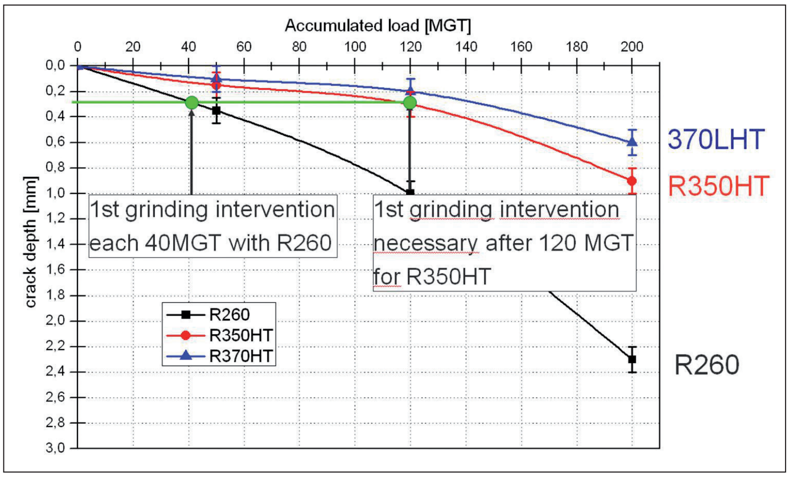


Fig 6. R350HT rail needed only half the number of grinding passes to remove head checks and produce the required profile compared to R260 rail.

measurement of the depth of any head-check damage, and the latest generation of grinding machines is equipped with eddy-current recording systems. These are primarily used to ensure that the damaged surface layer is removed completely, but no more, in order to maximise rail life. But the provision of regular information about metal removal and grinding cycles also helps railways and infrastructure managers to fine-tune their grinding regimes.

Track tests often also include investigation of their grinding requirements. R350HT rail needed only half the number of grinding passes to remove head checks and produce the required profile compared to R260 rail. Assuming the same interval between grinding, the amount of material to be removed is therefore much lower. The 370LHT and 400UHC rail required even less metal removal to remove any RCF cracking and restore the target profile (Fig 6)[5].

Based on these and earlier findings, Dutch infrastructure manager ProRail has already adopted a new rail management strategy combining the use of advanced pearlitic rail steels with an optimised rail/wheel profile and a preventive grinding strategy. ProRail is using 370LHT grade rail and the 54E5 AHC profile which provides gauge-corner relief to reduce crack propagation in all curves up to 3 000 m radius. It has also adopted a preventive grinding strategy for ongoing RCF management.

Life-cycle cost model

Technical requirements and economic benefits are not contradictory, and both can contribute to a sustainable railway system. As such, both operators and suppliers have a strategic goal to reduce life-cycle costs.

Numerous projects have been undertaken to quantify the economic impact of advanced rail steels and different rail maintenance strategies. Austrian Federal Railways and Voestalpine Schienen Technical Services have been working with the Institute for Railway Engineering at the Technical University of Graz to develop a dynamic software tool. Life-cycle cost analysis is used to calculate the cost-effectiveness of different rail grades and profiles, evaluating both the annualised capital cost and the cost of appropriate maintenance strategies over the entire service life of the rail[8]. By comparing the life-cycle cost of different rail grades and profiles, infrastructure managers can take more informed maintenance and investment decisions[3, 9].

Life-cycle cost analyses undertaken for Innotrack have confirmed the economic benefits to be gained from appropriate use of heat-treated rail on European networks, offering savings of up to 50% in rail costs on intensively-used track. This is equivalent to around 7% of total costs when the whole track system is taken into consideration, which is still impressive. These calculations suggest that the amortisation of the slightly higher capital cost for heat-treated rail can be achieved very rapidly, and in some cases within just two years of installation.

References

1. Girsch G, and Heyder R. Advanced pearlitic rail steels promise to improve rolling contact fatigue resistance. WCRR 2006, Montréal.
2. Girsch G and Heyder R. Head-hardened rails put to the test. RG 1.04 p42
3. Girsch G, Heyder R, Kumpfmüller N and Belz R. Comparing life-cycle costs of standard and head-hardened rail. RG 9.05 p549
4. Innotrack Deliverable D4.1.5GL. Definitive guidelines on the use of different rail grades.
5. Girsch G, Keichel J et al. Advanced rail steels for heavy haul applications – track performance and weldability. IHHA conference, Shanghai, June 2009.
6. Robles Hernandez F C and LoPresti J. Interim evaluation of premium rail steels at FAST. *Technology Digest* June 2007.
7. Innotrack Deliverable D4.5.5. Guidelines for management of rail grinding.
8. Frank N and Girsch G. LCC-RAIL: a software tool for life-cycle cost calculation. *Rail Engineering International* 2008 No 2.
9. Girsch G, Frank N and Pointner P. Life-cycle cost considerations on high-strength rail steels. WCRR 2008, Seoul.

Detailed reports from the Innotrack project are available at **www.innotrack.eu**

Two 48-stone grinding machines can be coupled together to undertake one-pass grinding.