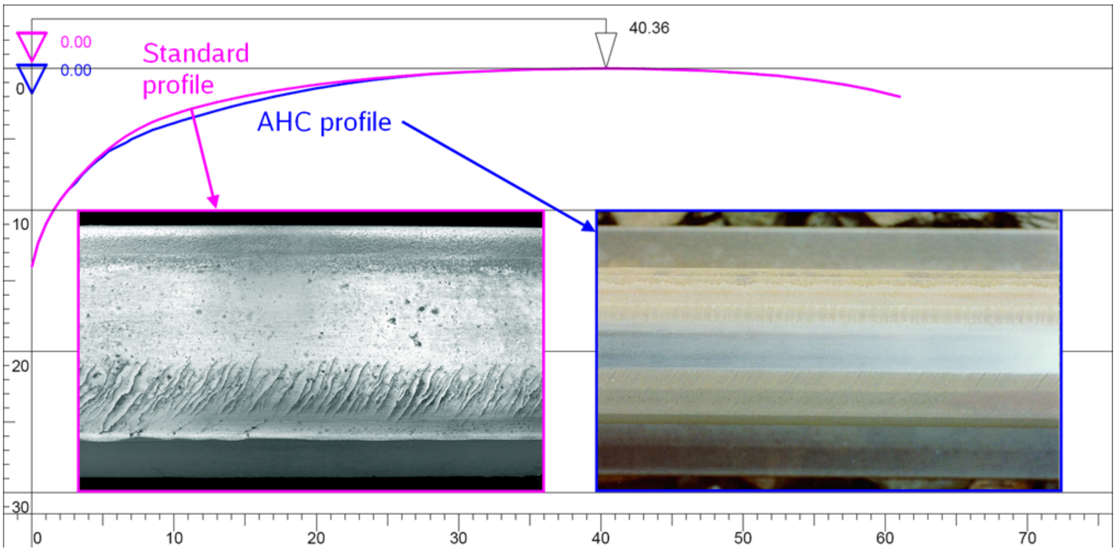
Integrated Project (IP)
Project No. TIP5-CT-2006-031415

Thematic Priority 6:
Sustainable Development,
Global Change and Ecosystems

# D4.5.5 - Guidelines for Management of Rail Grinding




## INNOTRACK GUIDELINE

## Table of Contents

# 1 Glossary

| Abbreviation/acronym | Description |
|---|---|
| AHC | Anti-Head Check |
| AHCC | Anti-Head Check Corrective |
| AHCP | Anti-Head Check Preventive |
| HC | Head Check |
| HR | High Rail |
| IM | Infrastructure Manager |
| LCC | Life cycle costs |
| LR | Low Rail |
| MGT | Million gross tons |
| RCF | Rolling Contact Fatigue |
| WP | Work Package |

## *1.1 Definitions*

As the technical terms used vary from one railway to the other, the following definitions have been fixed.

Rail maintenance in this deliverable means essentially rail rectification by using at present available technologies such as grinding, milling, planing etc.

<u>Maintenance Strategy</u>

This is a planned maintenance activity, usually defined by the infrastructure maintainer. It is in theory independent of available technologies, but in practice often influenced by the equipment that is easily accessible to or proposed by the contractors.

Work is either programmed depending on reaching predetermined intervention thresholds such as corrugation depth, deviation from the transverse profile and depth of cracks.

Alternatively work is executed in cycles, which are derived from experience and influenced by availability of machines, track possession times and similar factors, usually expressed in tonnage (MGT), months, seasons etc. Often work is combined with other maintenance activities (e.g. after rail replacement, after tamping, when the line is closed for other work, etc.).

Before the execution of rail maintenance work, specifications (i.e. the results that need to be achieved) have to be defined with respect to:

- Defect repair (metal removal)
- Longitudinal profile (evenness)
- Transversal profile (target and tolerance)
- Surface condition (roughness, facet widths, etc.)

Maintenance Process (the "hardware")

This is the technology and the respective equipment, which has been developed to achieve the purpose of the intervention:

- Grinding (rotating grinding stones, static abrasive blocks, oscillating grinding stones)
- Milling
- Planing
- High speed grinding

For the sake of simplicity in the following "Grinding" is used as general term for all these technologies.

Maintenance Procedure (the "software")

This is the utilisation of the equipment in order to produce the specified results. In the case of conventional rail grinding, it covers the positioning of grinding stones and stone pressure ("grinding pattern"), the grinding speed, the number of grinding passes, any required side works (e.g. stone changes, cleaning, etc.) and the work documentation (e.g. simultaneous continuous recording or spot-checks after termination of work).

# 2 Executive Summary

The work package WP 4.5 “Rail Maintenance”[1] started with a summary of the present rail grinding strategies, grinding specifications and target profiles used for rail grinding in order to identify potentials for improvements aiming at reducing LCC for the rails.

Generally European IM’s do not yet apply rail grinding to avoid or reduce RCF in a strategic way. Sporadic corrective actions are the usual means to solve more severe rail surface problems.

Based on the advanced experiences of the contributing IM’s, guidelines on how to manage rail grinding in order to maintain rails more economically and how to change towards a preventive cyclic grinding strategy have been elaborated in order to prolong rail service life and to reduce LCC.

In particular fields of improvement such as specifications and logistics as well as recommendations for an optimised use of target profiles for grinding work are proposed.

The guidelines will help IM’s to find the right solutions in optimising their maintenance work with respect to corrugation and especially RCF.

[1] Members of the working group were:

- Wolfgang Schöch, Speno (WS@speno.ch)
- René Heyder, DB (Rene.Heyder@deutschebahn.com)
- Rolf Dollevoet, ProRail (Rolf.Dollevoet@prorail.nl)
- Jean-Marc Pauchet and Julia Plu, SNCF (jean-marc.pauchet@sncf.fr, julia.plu@sncf.fr)
- John Amoore and Paul Richards, NR (John.Amoore@networkrail.co.uk, Paul.Richards3@ networkrail.co.uk)
- Jay Jaiswal and Rob Carroll, Corus (jay.jaiswal@corusgroup.com, rob.carroll@corusgroup.com)
- Peter Pointner and Richard Stock, VAS (P.Pointner@voestalpine.com, Richard.Stock@voestalpine.com)

# 3 Introduction

WP 4.5 consists of representatives from four infrastructure managers, two rail manufacturers and one grinding contractor. Contributions from two further infrastructure managers participating in other WP's have been implemented.

Although the data collected comes from only a few IM's, and may not be considered representative for all European railways, the results pointed to a number of reasonably well supported common practices, which form the basis of new or improved ways of rail maintenance strategies to prolong rail life and reduce LCC.

The results of this survey [3.1] regarding present rail grinding practices of represented IM's can be summarized as follows:

- The main reasons for grinding are corrugation, RCF and vehicle stability; usually they do not overlap.
- Each railway has specifications for rail grinding work. Apart from standard profiles, special target profiles are defined.
- In the case of RCF, gauge corner relief is generally specified.
- Grinding work can be classified as initial (pre-service), preventive cyclic and corrective work.
- Some railways specify grinding cycles.
- The combination of grinding with other track maintenance work is mentioned as preferred procedure, in particular tamping before grinding.

Contrary to the general situation of European railways, the IM's represented believe their practice to be more advanced and at a first glance satisfactory. However, thorough investigation revealed quite some potential for upgrading and consequently a priority list of possible improvements has been produced:

- At present a gap exists between theory (specifications) and practice (availability of budget and track possession possibilities). Thorough application of existing specifications will produce cost savings very quickly.
- Preventive strategies have to be favoured over corrective ones.
- Grinding cycles should be checked and defined depending on traffic, line characteristics and rail grade.
- Grinding cycles could be elongated by finding the best mix between metal removal, target profile and intervention period.

- Planning needs to be undertaken with a long-term approach (up to three years in advance).
- Improved planning of maintenance work will help to reduce maintenance costs considerably. By better use of shift time (longer track possession intervals, longer working shifts) and higher working speeds allowing a "slow moving train" grinding approach, site productivity could be increased and costs per meter of track reduced.
- The propensity for vehicles to produce rail damage from factors which include the wheel profiles used, their condition and bogie primary yaw stiffness, needs to be minimised. Wheel profiles should be examined and maintained within tight limits in order to optimise rail maintenance. High impact vehicles should be identified and respective fines should apply.

INNOTRACK is essentially a European project dealing with mixed traffic lines, carrying passenger and freight traffic with usual moderate axle loads (22.5 tons) and higher speeds (up to 200 km/h on standard routes; up to 300 km/h on dedicated high-speed lines).

Because of their different conditions (traffic characteristics, vehicle characteristics, operational conditions, high axle load, low speed, hollow-worn wheels) it did not seem appropriate to undertake a detailed investigation in overseas rail maintenance practises as e.g. coming from North America and Australia and therefore such experiences have not be implemented in the documents of WP 4.5.

However, the heavy-haul approach of using specific target profiles and cyclic grinding interventions keeps their RCF problem under control and coincides with the considerations made under European conventional conditions.

## 3.1 Bibliography

3.1 INNOTRACK Deliverable D4.5.1, *Overview of existing rail grinding strategies and new and optimised approaches for Europe.*

# 4 Corrugation control

Periodic irregularities on the rail surface appear usually either as short pitch corrugation in tangent track or short wave formation in curves on the low rail (Figure 4-1). According to their appearance and location several other sub-types have been identified [4.1].

*Figure 4-1: Short pitch corrugation (left) and short wave formation (right)*

Besides track deterioration (due to dynamic forces acting on fastening systems, sleepers, etc.) corrugation causes especially in densely inhabited areas a major noise problem. In the case of short-pitch corrugation on high speed lines RCF defects can result (Figure 4-2) [4.2].

Therefore the removal of corrugation is one of the two main applications of grinding.

*Figure 4-2: Short-pitch corrugation on high speed lines with belgrospi's*

## 4.1 Intervention control

Corrugation measurements allow detecting sections, where grinding is required but also to program the necessary working shifts and track possession times in detail.

As noise levels increase with growing corrugation depth the intervention threshold is often set at 0.05 mm peak-to-peak depth for short pitch corrugation, which also helps to minimize dynamic forces as track vibrations start to damage the ballast structure at that level and to reduce the risk for subsurface initiated RCF of wheels and rails. The value of 0.05 mm is recommended for general use, higher intervention thresholds are not suitable.

Some defect types require a lower intervention threshold of 0.03 mm (e.g. belgrospi’s).

With regard to short waves on low rails in sharp curves intervention values between 0.1 mm and 0.3 mm have been fixed.

## 4.2 Target conditions

Acceptance criteria for rail grinding work are defined in [4.3].

# 4.3 Bibliography

4.1 P. Weidinger, *Rauhigkeit im Rad-Schiene System*, Diploma Thesis, 2008

4.2 H.-D. Grohmann, K. Hempelmann and A. Groß-Thebing, *A new type of RCF, experimental and theoretical investigations*. Proceedings of the 5th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems, Tokyo, 25–28 July 2000, pp. 167 – 170.

4.3 EN 13231-3, *Railway applications – Track – Acceptance of works – Part 3: Acceptance of rail grinding, milling and planing work in track.*

# 5 RCF control

In addition to material wear, the service life of rails today is more and more limited by RCF. The most common rail failures are head checks (Figure 5-1), belgrospi's (Figure 4-2) and squats (Figure 5-2).

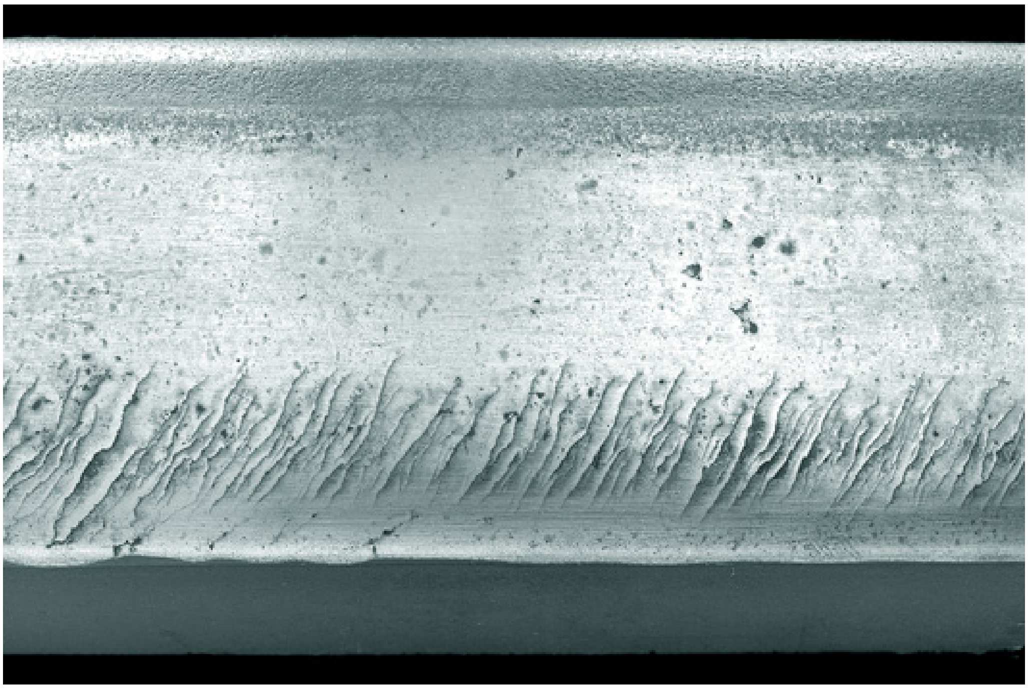


*Figure 5-1: Head checks at the gauge corner of a high rail*

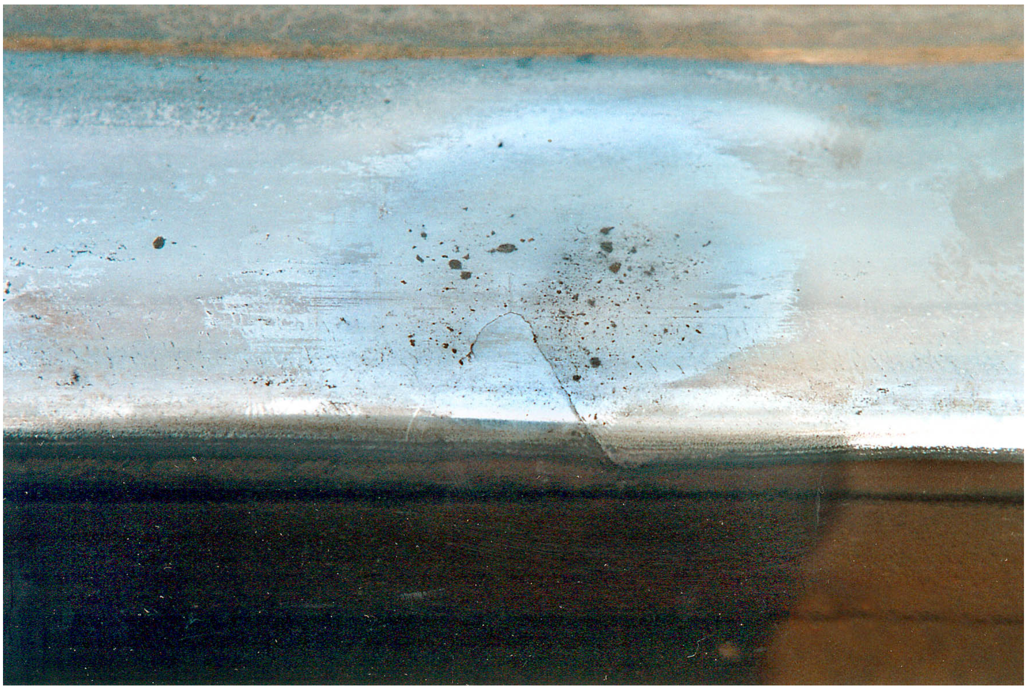


*Figure 5-2: Squat on the running surface in tangent track*

## 5.1 Basic strategy

RCF can be effectively controlled when the shape of the rail head profile matches the prevailing wheel profiles and when the fatigued rail surface is regularly removed in appropriate intervals.

As a rule grinding should always be carried out as soon as possible after re-railing in order to introduce or optimise the target profile (wheel-adapted or AHC profiles).

In order to assure a long rail service life and consequently low LCC the consecutive grinding cycles need to be programmed from the beginning.

## 5.2 Target profile

Standard target profiles are usually applied when grinding rails [5.1]. These profiles are normally identical to the as-rolled profiles. For special applications, different target profiles are in use, such as asymmetric profiles to reduce lateral wear of high rails in sharp curves and gauge widening profiles to lower the equivalent conicity [5.1].

In order to control RCF in head check sensitive areas, on the high rails in shallow curves, the use of an AHC profile is recommended [5.1]. Figure 5-1 shows some examples used by different IM's. Whilst the basic idea behind these profiles is similar they differ in detail. They are characterised by specifically grinding more metal off the gauge corner in order to achieve lower contact stresses. A minimum undercutting of 0.3 mm with respect to the standard target profile is a reasonable approach, as such a profile provides a delayed appearance of head checks.

Profile 54E5 (= 54E1 AHC), which is at present the only AHC profile to be incorporated in EN 13674-1 is recommended as a suitable starting point in order to harmonize the various existing AHC profiles.[2] Production tolerances of +/- 0.3 mm should be maintained in order to minimize wear.

There is unanimous acceptance that preventive cyclic grinding with limited metal removal requirements should be executed, applying profiles with moderate gauge corner relief. If maintained in proper

[2] For rails with larger rail heads the shape has to be adapted accordingly.

cycles, metal removal can be adjusted for a one-pass grinding regime as well.

More severe undercutting at the gauge corner should only be considered in the case of corrective work (see chapter 5.4).

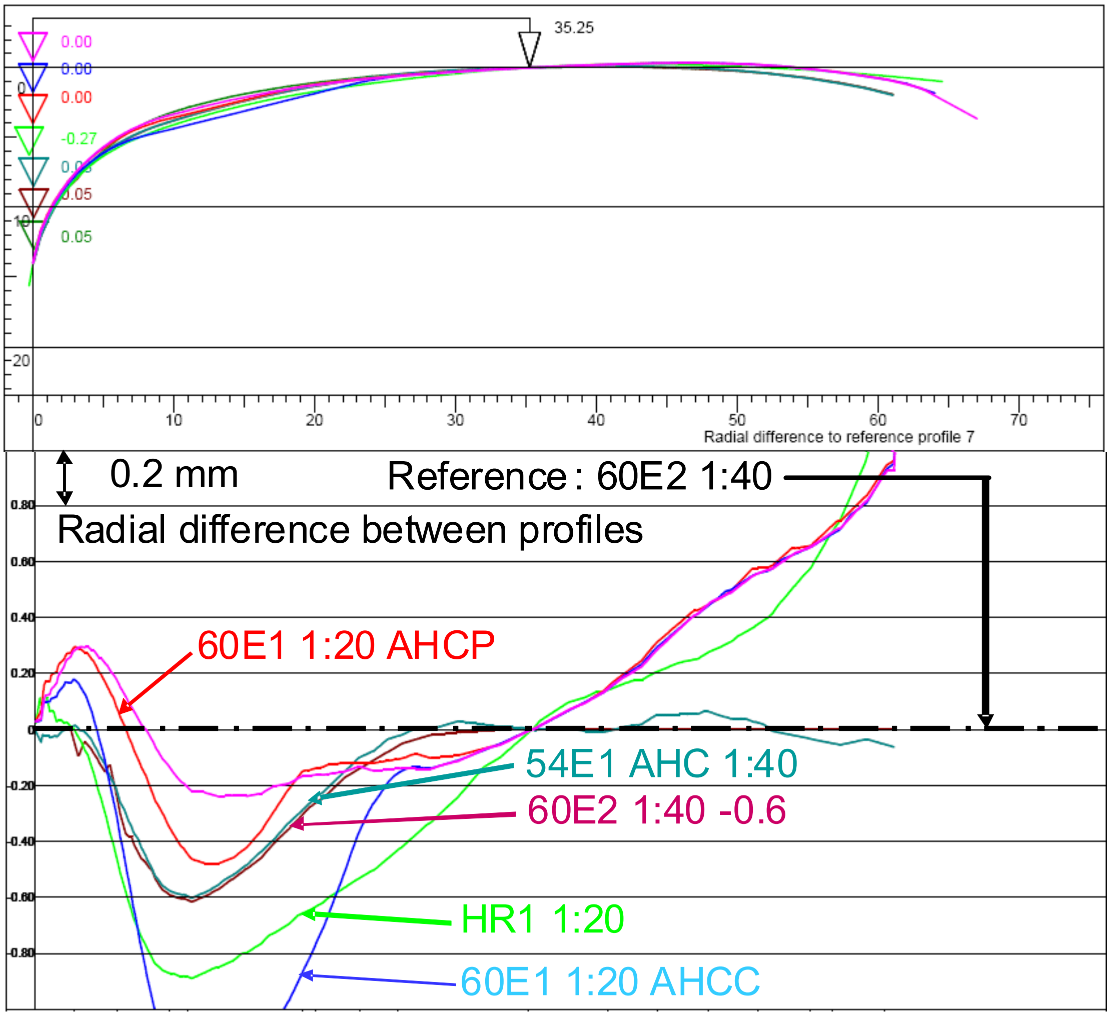



*Figure 5-3: Comparison of AHC profiles: The reference profile is the 60E2 1:40 (bold line) and the reference points are the rail head centre 0°- tangent and 14 mm below at gauge; the radial difference to the reference profile is given beneath.*

## 5.3 Metal removal and grinding cycles

In order to maintain HC sensitive rails economically a certain damage level can be accepted (as intervention threshold or as remaining crack depth after treatment) – small enough to be removed in a short time and not interfering with safety issues, and of a certain dimension not to require intervention too often, in order to reduce interference with traffic.

Basically, it must be kept in mind that the longer the grinding interval, the higher the metal removal rate and – most importantly – the longer the subsequent period for the growth of surface deterioration (RCF, wear, corrugation etc.). Equally, the ratio of natural wear by traffic over artificial wear by grinding needs to be well balanced.

Under the given present circumstances a reasonable approach is to aim at repetitive maintenance work with easily achievable metal removal rates and the least possible interference with track operations. Consequently a metal removal of up to 0.6 mm at the critical gauge area and a maximum of 0.2 mm in the centre of the rail head should be envisaged.

The grinding interval and the related average metal removal should depend on actual HC measurements (e.g. eddy current technology), which needs to be checked again during grinding work. Such a policy limits artificial wear by grinding.

Acceptance criteria for rail grinding work are defined in [4.3].

## 5.4 Transition strategy

In order to implement a preventive cyclic strategy for a given track section, line or network, circumstantial corrective actions are required in order to bring this track section, line or network up to a suitable initial condition regarding grinding requirements before the cyclic strategy can be implemented. This implies a heavy initial investment in maintenance followed by economically beneficial cyclic measures.

In order to move from a corrective maintenance regime to a preventive cyclic one, the following steps are proposed:

- Measurements and documentation of the actual situation with regard to RCF
- Classification of the track sections in the following categories:
  - Preventive cyclic work sufficient
  - Corrective work required
  - Heavily damaged (to be replaced in due time)
- Prioritisation of required corrective actions:
  - Corrective to zero (preventive mode) in one step (preferred scenario)
  - Corrective to zero (preventive mode) in several steps (in case of limited budget or grinding capacity)
  - Keep present situation by cyclic interventions (minimal solution)

- Continued strategic preventive actions:
  - all good or corrected sections to be kept in the preventive cyclic mode
  - Switch to a maintenance philosophy that prioritises preventive cyclic work over corrective actions

## 5.5 Bibliography

5.1 INNOTRACK Deliverable D4.5.2, *Target Profiles.*

# 6 Organisation and operational considerations

When establishing a strategic RCF controlling approach, logistical issues need to be addressed as well: grinding interventions require track possession time. If the grinding technology used matches all requirements, high production rates at comparatively low prices can be expected. When working in cycles (for any given surface problem) all other irregularities such as corrugation, imprints, squats etc. will be controlled or eliminated simultaneously and their negative effects removed.

Grinding work reduces dynamic forces and vibrations and thus helps to decrease track degradation. It therefore should be, whenever possible, coordinated with other track maintenance activities, following tamping, in particular.

Metal removal rates depend on maintenance cycles, which in themselves depend on machine availability, operational and budgetary aspects. It is not appropriate to ignore such conditions, but to integrate them as much as possible in flexible regimes.

Conventional rail grinding offers solutions for all rail maintenance applications where metal needs to be removed. In the case of higher metal removal requirements (corrective actions) milling is a feasible alternative. Rail planing may be used to repair the transverse profile in areas with strong wear, e.g. tight curves, or for heavy failure removal. For very low metal removal rates high speed grinding could become a future solution.

## 6.1 Logistics

Usually grinding concentrates on problematic areas often dispersed geographically. As depots for the grinding machines are located at considerable distances (sometimes over 100 km) from worksites, the grinding machines have to be transferred every day over long distances (usually as low priority trains), thus precious working time is lost. Due to the heavy organisational work on site for activating pre-programmed possessions, further time is lost during the work shift.

RCF grinding should be programmed strategically. An ideal maintenance plan consists of the following seven points:

1) A regular preventive cyclic grinding program covering a whole line

2) Possession times organized accordingly, i.e. as effectively as possible

3) Depots adapted to the maintenance requirements of the machines available at strategic points

4) Grinding machines (size to be adapted to required metal removal in a one-pass operation) to start from the first depot and to move over the line in order to grind wherever required

5) Working speed depending on the required metal removal (grinding cycle) and used technology

6) On-board recording equipment able to document the work undertaken and its quality without the need to check the result in track

7) Optimized organisation of daily grinding work to ensure that the ratio of working period over effective grinding time is maximised

Carefully planned machine deployment leads to cost reductions. Internationally, production time (time for grinding, reversing, measuring, cleaning) amounts to about 60 % of the machine deployment time at present. If the ratio of production time over deployment time could be increased to 70 %, this would lead to a cost reduction of 14 % [6.1].

Predictable time requirements are favourable – multiple pass work should be limited. Production rates will increase tremendously when uninterrupted one-pass grinding can be executed. With an average grinding speed of 10 km/h it should be possible to achieve a production rate of up to 50 km per work shift.

## *6.2 Contracting issues*

At present, grinding contracts are directly or indirectly based on daily shift prices, which determine the costs for a finished kilometre. As very often the grinding equipment is used over short sections (problematic curves) often many kilometres apart, and corrective work requires a higher number of working passes, the price per finished meter is fairly high.

In order to reach the ideal situation described in chapter 6.1, high-capacity machines need to be used. The investment required for them is only justified when these machines can work in a constant high-production regime.

Grinding contracts should cover periods of several years, allowing lower basic rates for daily shifts and further reducing costs per finished meter. Short grinding sections requiring multiple passes would be attributed to more flexible compact machines.

## 6.3 Bibliography

6.1 T. Hempe and T. Siefer, *Rail grinding as an integral part of technically and economically efficient track maintenance*, Rail Engineering International, Edition 2007, Number 3, pp. 6 - 12

# 7 Conclusions

Modern railway traffic operation provokes at many places (though depending from local, operational conditions) rail surface fatigue phenomena, usually referred to as RCF. Head checks and similar defects develop sooner or later. The rail steel quality plays a determining role, but there is no material available at present, which can withstand fatigue entirely. Furthermore the majority of rails in track today, with adequate but lower fatigue resistance, has a future life span, which makes it much more economic to maintain them in an appropriate manner rather than to change them.

Thus, rail maintenance is an inevitable must. Predictable work - at least in a medium time horizon - organised in a strategic way needs to be defined, in order to profit most from existing technologies and to guide the industry for future development. However, it must be assured that the chosen approach provides enough flexibility to adapt to changing situations in both directions: Increased requirements for maintenance due to higher loads and dynamic forces, reduced requirements for maintenance due to lower loads (improved vehicle characteristics) and better performing rails (reduced fatigue development).

Based on current practice and foreseeable developments rail maintenance can be classified in three sectors:

- Preventive initial work on short to long sections
- Corrective work on (more or less) short sections dispersed over the network
- Preventive cyclic work on (as much as possible) long sections

Depending on the size of a railway network a certain number and different types of machines may be required. The third mentioned sector applies specifically to RCF-treatment. It must be emphasized that any maintenance regime has to assure ideal wheel-rail contact conditions (optimal rail profile within tight tolerances) and ideal metal removal rates (big enough to eradicate defects but as low as necessary in order to keep artificial wear at a minimum).

The use of specific target profiles featuring gauge corner relief (AHC profile) is recommended as they delay the appearance of head checks and thus contribute to longer grinding cycles.

Under the given present circumstances a reasonable approach aims at repetitive grinding work with easily achievable metal removal rates and the least possible interference with track operations. Consequently a metal removal of up to 0.6 mm at the critical gauge area and a maximum of 0.2 mm in the centre of the rail head should be envisaged. Such work can be done by modern grinding machines in one pass at working speeds of up to 10 km/h. This allows – depending on work planning – to finish up to 50 km of maintained track per work shift.

If defects are deeper (longer maintenance interval) such a grinding machine could work in a one-pass regime at lower speeds (down to about 3 km/h) or the use of bigger machines can be considered. Defects smaller than the above mentioned do not pose a problem for the rails but would increase organisation, supervision and execution of work.

Future machine development should aim at even higher – but controllable – working speeds with the same metal removal capacity range.

In this context it is important to announce future grinding needs and capacities to the grinding industry as early as possible. Such information allows building and providing production capacities in an economic way. The benefit is then two-fold: On one-side, optimal rail surface conditions prolong rail life and reduce general track deterioration (save money in the long run), on the other hand present maintenance costs (grinding) can be reduced considerably.