Recommendations for strategic rail maintenance in Europe: the application of anti-headcheck profiles and cyclic grinding

In Europe, rail maintenance is about to change, as new recommendations, entailing the application of anti-headcheck profiles and cyclic grinding, which result from the European research project INNOTRACK, are about to be implemented. This article summarises the work undertaken by the WP 4.5 working group of the INNOTRACK project. In this respect, it first looks at the current rail maintenance practices adopted by a number of European rail infrastructure managers and then addresses the proposed recommendations.

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The "INNOTRACK" project, supported by the European Commission, contained, amongst others, work package WP 4.5, entitled "Innovative Maintenance Processes". WP 4.5 looked for new or improved ways to combat the various forms of rail defects (Figs. 1, 2 and 3), aimed at extending the service life of the rail, as well as reducing its life-cycle cost (LCC).

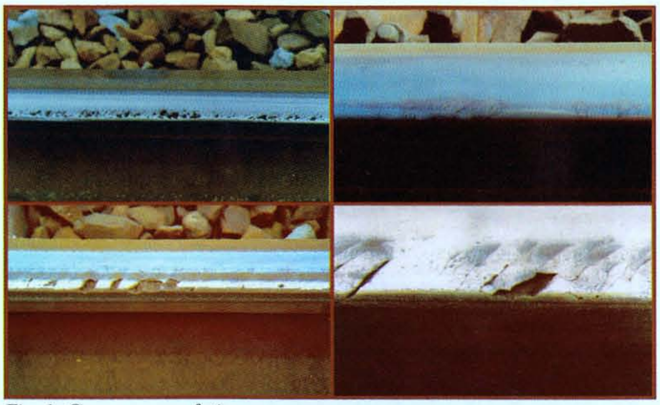

Fig. 1: Gauge-corner fatigue

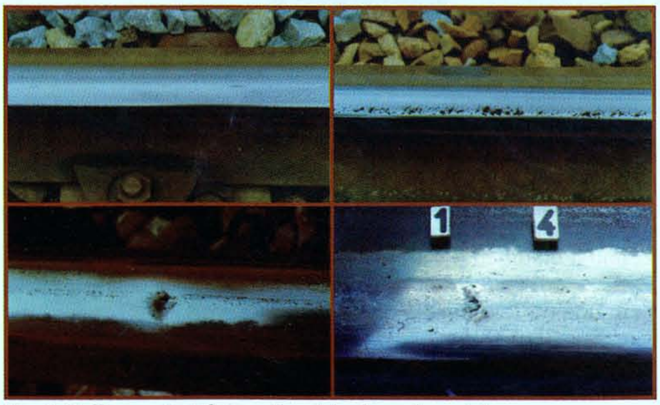

Fig. 2: Rolling contact fatigue (headchecks and squats)

Fig. 3: Head checks

The members of the WP 4.5 working group embraced representatives from the following four rail infrastructure managers, two rail manufacturing companies, and one rail grinding contractor:
— DB Netz AG (Germany);
— SNCF (France);
— Network Rail (UK);
— ProRail (The Netherlands);
— Corus Rail (now Tata Steel);
— voestalpine Schienen GmbH;
— Speno International S.A.

The work package WP 4.5 embraced two parts:
— the first part entailed the making of an inventory of the current situation with respect to applied target profiles and rail maintenance practices, while seeking areas for improvement;
— the second part entailed the compilation of recommendations to improve rail maintenance practices, aimed at minimising rail wear and rolling contact fatugue (RCF), thus increasing the service life of the rail and reducing its LCC.

In this article, a summary of the work undertaken by the WP 4.5 working group is given.

CURRENT RAIL MAINTENANCE PRACTICES

As noted earlier, the WP 4.5 working group first looked at the rail maintenance practices currently applied by the rail infrastructure managers participating in the WP 4.5 working group, i.e. DB Netz AG, SNCF, ProRail and Network Rail. In this respect, an inventory was made of currently applied:
— anti-headcheck profiles;
— rail grinding strategies.

Currently applied anti-headcheck profiles

In addition to standard profiles and rail laying angles, all the rail infrastructure managers participating in the WP 4.5 working group apply specially shaped rail profiles, the so-called anti-headcheck (AHC) profiles, in order to lower wheel/rail contact stresses and, thus, reduce gauge-corner fatigue [1].

With respect to the rail infrastructure managers participating in the WP 4.5 working group, the following five AHC profiles were identified [2]:
— DB Netz AG: the 60E2 -0.6 (the designation "-0.6" describes the undercutting of the initial profile at the gauge corner);
— SNCF:
  — the 60E1 AHCC (Anti Head Check profile for Corrective purposes);
  — the 60E1 AHCP (Anti Head Check profile for Preventive purposes);
— ProRail: the 54E1 AHC (now named 54E5);
— Network Rail: the NR HR1.

Whilst the basic idea behind these AHC profiles, which are applied in the head-check sensitive areas (usually the high rails in curves) is similar, they differ in detail (see Fig. 4).

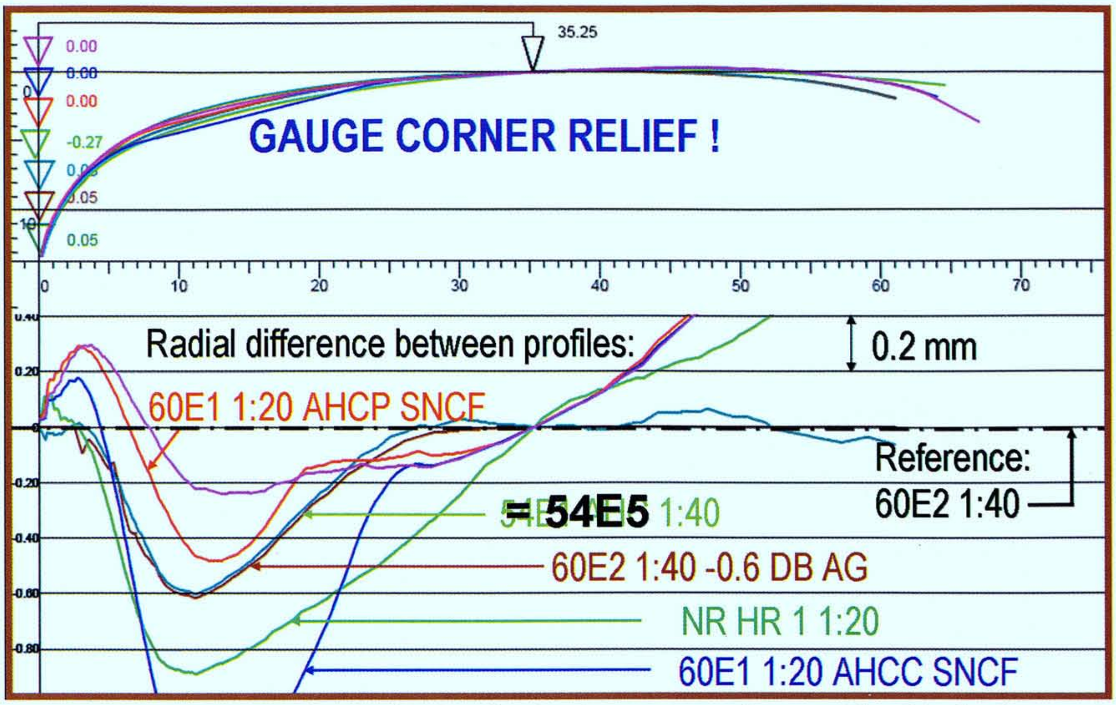

Fig. 4: Comparison of anti-headcheck profiles: the reference points are the centre of the rail head and 14 mm below at the gauge corner; the radial difference to the reference profile is shown at the bottom of the illustration (the reference profile is the 60E2 1:40 (bold line))

The following observations can be made with respect to the five AHC profiles [2]:

— the NR HR1 (Network Rail) provides a consistently lower shape from the centre to the gauge side of the rail and a higher one from the centre to the field side of the rail;

— the difference between the two AHC profiles applied by SNCF is that the corrective profile 60E1 AHCC has more undercutting at the gauge corner of the rail than the preventive profile 60E1 AHCP. As a result, the 60E1 AHCC has a distinguished lower zone at the gauge corner;

— the 60E1 AHCP (SNCF), the 54E1 AHC (ProRail) and the 60E2 -0.6 (DB Netz AG) have similar shapes at the gauge corner, with the latter two, i.e. the 54E1 AHC and the 60E2 -0.6, providing virtually identical wheel/rail contact conditions.

All three profiles require a maximum of 0.6 mm undercutting at the gauge corner of the rail. They combine moderate crack removal and gauge-corner relief as a way to minimise the amount of metal that needs to be removed. With heavy-duty grinding machines, this can be achieved in one-pass, making the three profiles ideal for cyclical maintenance grinding.

The other two profiles, i.e. the 60E1 AHCC (SNCF) and the NR HR1 (Network Rail) require metal removal in more than one pass. However, if maintained in proper cycles, the metal removal rate could be adapted at some stage to also allow one-pass grinding.

As noted earlier, the preventive anti-headcheck profiles that feature up to 0.6 mm gauge-corner undercutting provide rather similar wheel/rail contact conditions. Standardisation of these profiles seems desirable. However, due to the fact that wheel/rail contact conditions depend also on rolling stock characteristics (wheel profile, bogie stiffness, etc.), the rail infrastructure managers participating in the WP 4.5 working group do not consider it possible to propose a uniform preventive anti-headcheck profile for general use.

Standardisation of rail profiles would require cooperation of wheel/rail contact experts from both sides (track and rolling stock), as running stability (equivalent conicity), derailment risk (wheel climbing) and fatigue issues need to be addressed. Therefore, the aforementioned AHC profiles should only serve as guidelines for railways not yet applying AHC target profiles. By applying them, gauge-corner fatigue is reduced, as well as the respective maintenance cost. They are therefore recommended for use Europe-wide.

Currently applied rail grinding strategies

In Europe, apart from few exceptions, there are yet no specific, let alone harmonised, rail grinding strategies. Rail grinding is mainly carried out to control corrugation and related noise problems. Occasionally, but increasingly, grinding is carried out to remove severe rolling contact fatigue (RCF), a problem that is increasing on both conventional mixed-traffic and dedicated passenger high-speed lines in Europe. Also, budgets available for rail grinding are usually insufficient for the application of a strategic maintenance regime. Thus, short-term reactive needs (repair of damaged components) take precedence over the development of a long-term approach (prevention of damage, in order to reduce LCC).

Within the framework of the INNOTRACK project, an inventory was made of the rail grinding strategies currently applied by the four rail infrastructure managers participating in the WP 4.5 working group, i.e. DB Netz AG (Germany), SNCF (France), ProRail (The Netherlands) and Network Rail (UK).

DB Netz AG

For checking the condition of the rail, DB Netz AG uses rail inspection trains based on eddy-current and ultrasonic technology, which are able to examine the rail at speeds of up to 100 km/h. The point in time at which rail maintenance is carried out (grinding or renewal) depends on the depth of the measured damage and on the results obtained by ultrasonic testing.

In 2008, a preventive cyclic rail grinding programme was introduced for rails in curves with radii of between 500 m and 5,000 m on high-capacity lines (40% of the overall network), whereby a metal removal rate of 0.5 mm is aimed at. The rail grinding interval depends on tonnage of traffic carried, and varies from 0.5 to 2 years. The target profile is the standard 60E2 with an inclination of 1:40, whereby – different from usual grinding practices – only negative production tolerances (0 to -0.6 mm) are allowed.

SNCF

Until 2007, rail maintenance in France was carried out only for corrective purposes. On conventional lines, rail grinding was scheduled when headchecks could be visually detected, or influences on track geometry became apparent. On high-speed lines, rail grinding was carried out when ballast stone imprints or headchecks occurred.

In 2008, a new rail maintenance strategy was implemented. It entails:

— preventive cyclic rail grinding on all main lines;
— a gradual reduction in the amount of corrective rail grinding, which eventually should become an exceptional action;
— a continuous treatment of railway lines with variable metal removal rates and at variable grinding speeds, depending on the prevailing rail condition;
— long-term programming of grinding interventions, so that longer track possessions can be organised, in order to increase the productivity of rail grinding sites and, thus, reduce costs.

The application of the special anti-headcheck profiles mentioned earlier, i.e. the AHCC and AHCP, has resulted in an extension of the service life of the rail by at least five years, a finding that is supported by a study conducted by the SNCF Infrastructure Maintenance Division [3].

ProRail

In The Netherlands, preventive cyclic grinding was introduced in 2005, through the adoption of a grinding policy proposed by the National Research Council of Canada. It took two years before the preventive grinding policy could be implemented on the entire railway network, as first a zero damage level had to be reached by corrective grinding wherever necessary (corrective grinding was executed six to nine months after inspection by a measuring train). Thus, 2007 saw the start of a 100% preventive cyclic grinding policy for straight track and curves, as well as switches.

In principle, any preventive cyclic grinding starts with the initial grinding of new rails just after their installation. The best results are achieved by grinding within six weeks following installation, with a maximum of three months in exceptional cases. A minimum of 0.5 mm of metal is removed, the target profile for rails in straight track and curves being the 54E1. For rails in switches and the high rails in curves with radii smaller than 3,000 m, the anti-headcheck profile 54E1 AHC is adopted.

Preventive cyclic grinding is executed after every 15 MGT of traffic borne in curves with radii smaller than 3,000 m, after every 30 MGT in curves with radii of between 3,000 m and 9,000 m, and after every 45 MGT in curves with radii larger than 9,000 m. Here, the target profile for rails in straight track is the 54E1, and for the high rails in curves it is the 54E1 AHC. One-pass grinding is adopted, whereby a minimum of 0.2 mm of metal is removed.

Since the introduction of the preventive cyclic grinding strategy, a significant reduction in rail maintenance costs has been achieved [4].

Network Rail

At present, Network Rail uses three large rail grinding machines for operation on plain track in single-pass regimes, capable of grinding 32 km of curved track or 96 km of straight track per overnight shift. Additionally, three smaller grinding machines are used; these operate in multiple-pass regimes, allowing a much lower output per shift.

On Network Rail, rail grinding is prioritised, so that the highest priority curves with radii smaller than 2,500 m, as well as switches and crossings, are ground after about every 15 EMGT (equivalent million gross tons) of traffic borne, and straight track after every 45 EMGT.

Where RCF exists, grinding of long worksites (usually several kilometres long) is carried out, so as to produce a uniform running band towards the crown of the rail. This technique relieves loading of the cracked area, thus slowing down further deterioration of existing cracks (grinding of cracked rail may not remove the cracks unless they are very small and shallow).

All rails are ground to the same nominal profile, i.e.:

— for the high rails in curves, the NR HR1 anti-headcheck profile is used, which provides additional relief to the gauge corner of the rail;
— for all other rail, the NR 113 lb profile is used, which is a low rail profile that is equivalent to a new BS113A or a 56E1 profile.

A production tolerance of 0 to -0.6 mm may be used, the aim being to keep the profile close to the lower (-0.6 mm) tolerance.

In order to maximise the grinding productivity, Network Rail grinds on a site and/or route-specific basis, where the target profile, but not the minimum metal removal rate, needs to be achieved. Where necessary, this may result in little or no metal removal from the centre of the rail head.

RECOMMENDATIONS FOR STRATEGIC RAIL MAINTENANCE FROM THE WP 4.5 WORKING GROUP

When the INNOTRACK project was initially launched, it was thought that perhaps completely new rail maintenance technologies would have to be developed to help reduce the LCC of the rail. Although this has not been the case, it has been found that there is a great potential for improving the effects of the existing rail grinding technology.

After reviewing the rail grinding strategies and the target profiles currently in use, the WP 4.5 working group investigated the potential for improvements that could lead to an extension of the service life of the rail and, thus, reduce its LCC.

This has resulted in recommendations with respect to [5]:

— the initial grinding of newly installed rails;
— the application of strategic preventive rail grinding;
— the optimisation of existing rail grinding specifications;
— the optimisation of grinding machine logistics;
— the steps to be taken to enable the implementation of the preventive cyclic rail grinding strategies.

Initial grinding of newly installed rails

In general, initial rail grinding is carried out after the track of newly constructed railway lines, in particular high-speed lines, has been laid, and also after the renewal of long sections of rail (re-railing). Due to operational restrictions, it may be up to six months after re-railing that initial rail grinding is carried out.

For initial grinding of newly installed rails, a number of rail infrastructure managers in Europe specify target profiles that are different from the as-rolled ones, for instance wear-adapted profiles that are aimed at better accommodating hollow-worn wheels (e.g. adopted on the ore line "Malmbanan", in Sweden), low-conicity profiles (adopted on Austrian Federal Railways (ÖBB)). Also, on DB AG and Banverket (Sweden), in view of anticipated gauge-corner fatigue, only negative tolerances (e.g. 0/-0.6 mm) are specified.

The WP 4.5 working group recommends that, with respect to initial grinding of newly installed rails, rail grinding should be carried out with optimised target profiles, e.g. wear-adapted profiles or anti-headcheck profiles with appropriate production tolerances (e.g. +/–0.3 mm).

It is also recommended that rail grinding should be carried out as soon as possible after re-railing.

Strategic preventive rail grinding

Basically, the longer a rail grinding interval is, the higher the required metal removal rate is, as rail surface problems and irregularities, such as corrugation and high internal stresses, have more time to develop. Thus, the ratio of natural wear caused by traffic over artificial wear resulting from rail grinding should be well balanced.

The WP 4.5 working group recommends cyclical grinding of rails, whereby the rail grinding intervals should be based on the results obtained by rail measurements, as well as on specified average metal removal rates – that need to be checked during rail grinding. Thus, artificial wear by rail grinding can be reduced. Also, specific target profiles with defined gauge-corner relief and respective production tolerances need to be applied.

A strategy that aims at a minimal metal removal rate of between 0.15 mm at the centre of the rail head and a maximum of 0.60 mm at the gauge corner (depending on the actual damage depth) is recommended. Metal removal rates depend on maintenance cycles, which in themselves depend on machine availability, as well as on operational and budgetary factors. It is important not to ignore these factors, but to integrate them as much as possible into flexible grinding regimes.

When working in cycles (for any given rail surface problem), other irregularities, such as corrugation, ballast stone imprints, squats, etc., will be controlled or eliminated simultaneously and their negative effects removed.

Rail grinding leads to a reduction in dynamic forces and vibrations and, thus, helps to reduce track quality deterioration. Therefore, whenever possible, rail grinding should be coordinated with other track maintenance activities, and in particular be carried out following tamping.

If wheel profile management were undertaken in a similar preventive manner with improved intervention thresholds, RCF could be further positively influenced, which could further reduce the LCC of the rail.

Optimisation of existing rail grinding specifications

The European CEN specifications for rail grinding mainly deal with acceptance criteria for the work performed. These criteria are applied by many European rail infrastructure managers. Intervention thresholds and/or grinding cycles, however, are rarely addressed, and requirements as to how the work should be organised and executed are not formalised. Also, specifications to ensure that grinding machines achieve the targets in an optimal manner, both technically and economically, do not exist.

The WP 4.5 working group recommends that rail grinding specifications should be issued that combine technical, operational and economic considerations. The optimal solution has to take into account the availability of suitable machinery, working conditions (e.g. depots, machine transfers, and duration of track possessions), as well as the amount of metal to be removed. The order of these three factors is not essential, as they all interact with each other in one way or another.

Optimisation of grinding machine logistics

When establishing a strategic approach to rail maintenance, logistical issues also need to be addressed: rail grinding interventions require track possessions. If the grinding technology adopted meets all requirements, high production rates at comparatively low prices can be achieved.

Usually, rail grinding has to be carried out at locations that are geographically dispersed. As depots for the grinding machines are often located at considerable distances from the worksites (sometimes more than 100 kilometres), every day, the grinding machines have to be transferred over long distances, usually as low-priority trains. As a result, precious working time is lost. Further time is lost, due to the various preparatory works at the worksite.

Also, rail grinding contracts are indirectly based on daily shift prices, which determine the cost for a finished kilometre of track. Often, the grinding equipment is used over short sections (e.g. problematic curves), usually many kilometres apart, with corrective grinding requiring several passes; this leads to a fairly high price per finished kilometre of track.

The WP 4.5 working group recommends that:

- rail grinding should be scheduled strategically: regular preventive cyclic grinding should cover a whole line, and track possessions be organised accordingly.
- depots or machine stabling sidings, adapted to the prevailing maintenance requirements of the machines, should be available at strategic locations. Ideally, the grinding machines (the size of which adapted to allow the required amount of metal to be removed in one pass) should start from the first depot and then move over the line, grinding wherever necessary;
- the working speed, depending on the required metal removal rate, should range from 3 km/h (exceptionally, in case of more severe defects) to a desired maximum of 20 km/h. At present, the operation of rail grinding machines is limited to about 10 km/h;
- available track possessions should be used as effectively as possible. The organisation of daily grinding tasks needs to be perfected, in order to ensure that the ratio of working time over effective grinding time is maximised;
- recording equipment on-board the grinding machines should be used to document the work and its quality immediately after it has been performed, thus obviating the need to check the results in a separate track possession;
- multiple-pass grinding should become exceptional. Production rates could be increased tremendously if uninterrupted one-pass grinding is carried out. With an average grinding speed of 10 km/h, it should be possible to achieve a production rate of up to 50 km/day. In this respect it should be noted that, in Germany, a test campaign embracing one-pass and two-pass grinding showed that one-pass grinding, using two 48-stone grinding machines working together in a 96-stone grinding train configuration, achieved very positive results (Fig. 5);
- machine deployment should be planned carefully, which should lead to cost reductions. Internationally, production time (manoeuvring, waiting for track possession, grinding, reversing, measuring, cleaning, etc.) amounts to about 60% of the machine deployment time at present. If the ratio production time/deployment time could be increased to 70%, this would lead to a cost reduction of 14%. For instance, with an estimated budget requirement of say EUR 50 million per annum, a saving of EUR 8.4 million would be achievable annually [6];
- ideally, high-capacity machines should be used. The investment needed for these is only justified when these machines can work in a constant high-production regime; For short grinding sections, requiring multiple passes, more flexible compact machines should be used;
- rail grinding contracts for maintenance should cover periods of several years, which would lead to lower basic rates per daily shifts.

Fig. 5: The 96-stone grinding train that was used for one-pass grinding during the test campaign conducted in Germany

Steps to be taken to enable the implementation of the preventive cyclic rail grinding strategies

Before any preventive cyclic rail grinding strategy can be implemented, circumstantial corrective rail grinding is required, in order to bring the respective track section, line or network up to a suitable initial condition. This implies a heavy investment in rail maintenance initially, but this will be followed by economically beneficial returns as a result of the cyclic measures to be implemented.

In order to move from a corrective rail grinding strategy to a preventive cyclic one, the WP 4.5 working group recommends the following steps:

- measurements and documentation of the current situation with regard to the condition of the rail should be made;
- sections of track should be classified into those requiring:
  - preventive cyclic grinding;
  - corrective grinding;
  - rail replacement;
- required grinding interventions should be categorised into rail requiring:
  - corrective grinding in one pass (preferred scenario);
  - corrective grinding (to bring it to a zero damage level, i.e. the preventive state) in several passes, in case of limited budget or grinding capacity;
  - the maintaining of the present condition by preventive cyclic interventions.

Once the rail of the respective track section, line or network has been brought up to a suitable initial condition, its condition should be maintained by preventive cyclic rail grinding as recommended by the WP 4.5 working group.

CONCLUSIONS

The WP 4.5 working group produced various reports, or deliverables (see Table), which can be found at the following internet address: www.innotrack.eu.

D 4.5.1	Review of Existing Maintenance Situation
D 4.5.2	Target Profiles for Grinding
D 4.5.3	Grinding Strategies
D 4.5.4	Lubrication, Friction Management
D 4.5.5	Guidelines for Management of Rail Grinding

Deliverables published by the INNOTRACK WP 4.5 working group

Once implemented, the new strategic rail maintenance policy recommended, entailing the application of anti-headcheck profiles and cyclic grinding, as well as an optimisation of existing rail grinding specifications and machine logistics, should see a significant change in rail maintenance in Europe that should lead to an increase in the service life of the rail, as well as lower LCC.

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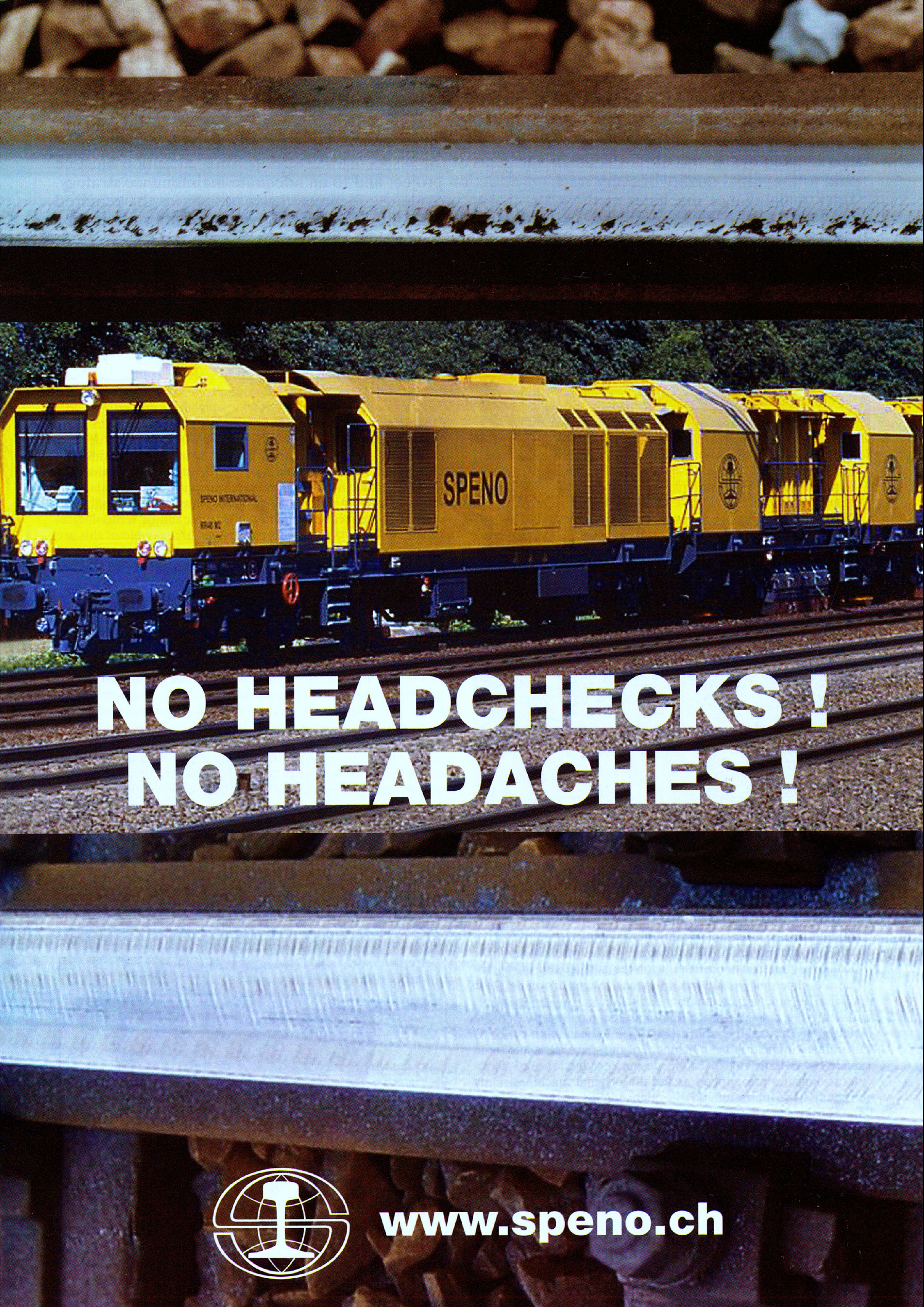
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