RAIL ENGINEERING INTERNATIONAL

Rail maintenance as a contribution to railway track optimisation

Railway track optimisation means providing the highest possible ride quality over the longest possible time span, at the lowest possible costs. This article addresses, in particular, the application of rail maintenance as a contribution to optimise the track and, thus, its availability.

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The rail is the main component of the track. Being in direct contact with railway vehicles, it bears the wheel loads and forces on an extremely small area. Consequently, a concentration of surface stresses occurs. The superimposition of high vertical and lateral forces, particularly in curves, brings the rail steel close to or even beyond the fatigue limit. This is due to the very complex geometry of two contacting bodies, both being curved differently in all directions. Thus, high traffic loads not only result in wear, but also in fatigue phenomena.

The following three areas of the rail are prone to wear and fatigue phenomena as a result of the undesired negative effects of high traffic loads, leading to an increase in maintenance work required and a decrease in track availability:

— *the longitudinal profile:* under traffic, geometric irregularities on the running surface may occur. In tangent track and in shallow curves, the occurrence of short-pitch corrugation is common (Fig. 1). Besides in a considerable increase in noise, they result in strong vibrations which lead to an increase in the dynamic loading of the track structure.

In sharp curves, short waves occur on the low rail as a result of insufficient rolling radius differential between the wheels running on the high rail and those running on the low rail (Fig. 2).

On lines which are mainly operated by the same type of traffic, often typical long waves can be observed (Fig. 3);

— *the transverse profile:* under traffic, the transverse profile of the rail head changes its shape as a result of wear. In tangent track and on the low rail of shallow curves, the rail head tends to flatten (Fig. 4). In sharp curves, the high rail tends to suffer from lateral wear on the gauge side; this increases as the curve radius decreases (Fig. 5). In some cases, plastic deformation may occur which can result in lips (Fig. 6);

— *the surface:* damage to the rail surface can also be caused by mechanical processes. For instance, by the imprint of ballast stones which have become air-borne during the passage of a train, or of other items (Fig. 7). Also, overloading of the rail steel - particularly in the case of unfavourable wheel/rail contact - results in hairline surface cracks, widely known as 'headchecks' (Fig. 8). These usually appear on the gauge corner of the high rail in shallow curves, but also on the running surface.

With high and often repeated loading, the headchecks eventually develop into particle loss of the surface, referred to as flaking or spalling, depending on its severity. Finally, gauge corner collapse may occur (Fig. 9).

When no counter-measures are taken with respect to the above-mentioned defects, then – sooner or later – this will result in the need for a premature replacement of the rail, i.e. prior to the end of its anticipated service life. Any measure which extends the service life of the rail is therefore welcome, so long as the costs of intervention are lower than those of a premature replacement of the rail.

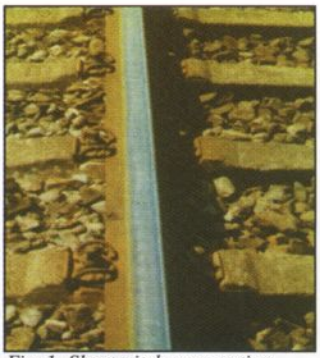
Fig. 1: Short-pitch corrugation

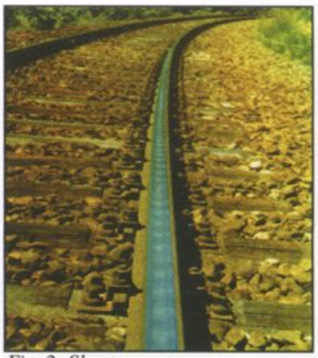
Fig. 2: Short waves

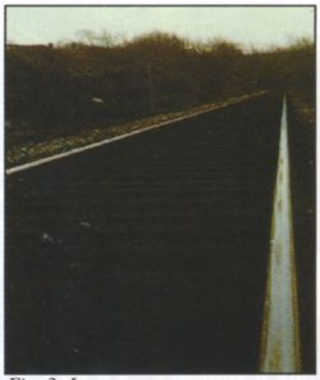
Fig. 3: Long waves

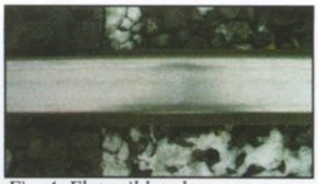
Fig. 4: Flat rail head

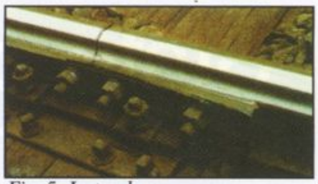
Fig. 5: Lateral wear

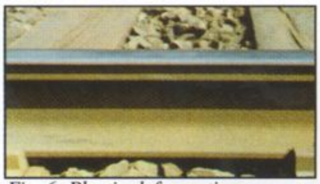
Fig. 6: Plastic deformation

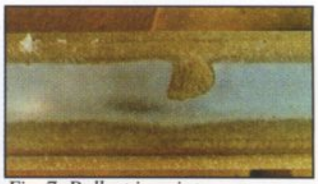
Fig. 7: Ballast imprint

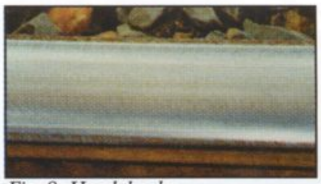
Fig. 8: Headchecks


Fig. 9: Gauge corner collapse

The negative effects of high traffic loads can be reduced by providing:

— *an impeccably smooth running surface:* geometric irregularities in the longitudinal plane result in higher dynamic forces due to vibrations. As a result, all the components which participate in the distribution of the loads undergo higher stresses and, thus, the risk of reaching or exceeding the fatigue limit increases. The situation can be optimised by providing an impeccably smooth running surface, with no corrugation whatsoever;

— *an optimal wheel/rail contact geometry:* by creating optimal wheel/rail contact conditions, the forces are transmitted uniformly into the rail steel, with a minimum of creep and wear.

It is essential to choose a transverse rail profile which best suits the passing wheels. In this respect, it should be taken into account that wheel profiles feature different shapes of wear and that they contact the rail head at different points, depending on local conditions. For instance, providing an asymmetric rail profile could reduce lateral wear of high rails in sharp curves (Fig. 10), whereas wear-adapted profiles may contribute to reducing the risk of surface fatigue (Fig. 11).

This can be effected by means of rail grinding.

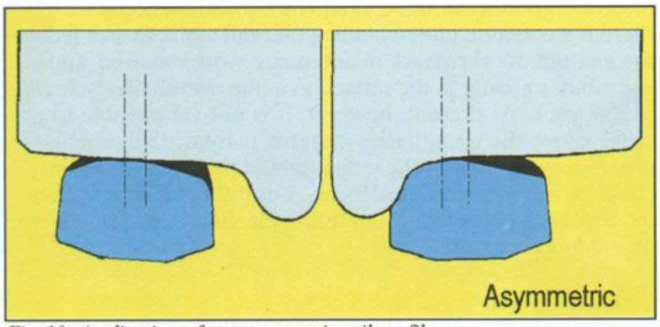

Fig. 10: Application of an asymmetric rail profile

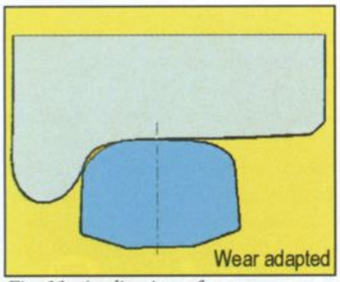

Fig. 11: Application of a wear-adapted profile

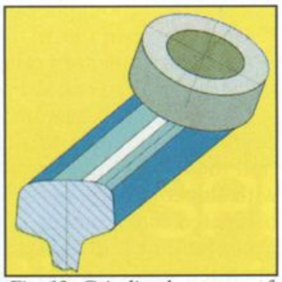

Fig. 12: Grinding by means of rotating stones

Optimisation by means of rail grinding

Rail maintenance generally means the in-track rectification of the rail head by means of large machinery, mainly rail grinding trains. By means of the latter, metal is removed in order to eliminate irregularities in the longitudinal profile. Simultaneously, metal is removed in order to correct the transverse profile. When fatigue defects are present on the running band or on the gauge corner these can be removed or, depending on their size, be reduced.

In-track rail grinding requires great care and skill. Rail and track are elastic and are sensitive to particular vibration ranges which are inherent to the metal removing process. Also, the required precision, e.g. transverse profiles requiring the removal of metal of some tenths of a millimetre, calls for specially designed machines and tools. At present, the grinding technique mainly deployed uses rotating grinding stones: a number of rotating grinding stones are pressed with their flat side onto the rail head (Fig. 12). Pre-set stone inclinations guarantee the shape of the transverse profile, described as a series of facets of varying widths like a polygon. Different types of grinding machines are available, ranging from small units featuring only four grinding stones, which are deployed to eliminate single defects, to machines featuring nearly a hundred grinding stones.

Basically, three types of action can be undertaken:

— *corrective action:* if the irregularities are allowed to reach a certain level of severity before they are eliminated, then this intervention is called repair or correction. Such a measure is applied whenever a rail maintenance strategy is launched for the first time. This type of intervention is applied to eliminate geometric irregularities, i.e. severe short-pitch corrugation, deep short-wave formation. or transverse profile deformation;

— *preservative action:* if only very small defects are allowed before they are eliminated, i.e. when a low intervention threshold has been fixed, then this intervention is called preventive grinding. This type of intervention is, for instance, applied to remove the initial stages of corrugation, i.e. featuring a depth of say 0.05 mm only.

The presence of defects is detected by means of regular inspections. This symptom-based intervention is applied to eliminate short-pitch corrugation and short waves which, depending on local parameters, develop at varying speeds;

— *preventive action:* in cases where no measurement data is available to enable the determination of defect severity, other parameters need to be applied in order to determine whether maintenance is required. For instance, surface fatigue cannot at present be detected and classified by means of non-destructive methods. In this case, fatigued metal is removed after a certain tonnage borne, expressed in million gross tons (MGT). This type of cyclical intervention is also called preventive grinding.

Strategic application

The timing of the maintenance activities is of significant importance. It is crucial to determine 'how', 'where' and 'when' something needs to be carried out, i.e. what maintenance strategy is to be followed. It should not be forgotten that rail grinding also involves artificial wear, i.e. wear induced by the metal removing process itself, and traffic disturbances. The table below presents a summary of rail grinding strategies.

Preventive Grinding (new rails): — provision of the best possible wheel/rail contact and running conditions; — minimisation of the impact of dynamic forces; — maximum delay of damage formation and development.
Corrective Grinding: — removal of severe corrugation and/or plastic deformation; — restoration of optimal wheel/rail contact and running conditions.
Symptom-based Grinding: — removal of corrugation at pre-determined intervention thresholds (e.g. short-pitch corrugation 0.05 mm in depth, short waves 0.35 mm in depth); — the intervention threshold selected should ensure an acceptable level of damage before rectification, and an economic defect removal by means of grinding.
Cyclical Grinding: — removal of the top surface layer in order to reduce surface fatigue; — minor correction of the transverse profile for optimal wheel/rail contact conditions; — intervention cycles depending on various local parameters, determined by experience or after a certain tonnage borne (e.g. after every 25 MGT).

The basis for an optimal rail grinding strategy is knowledge about the development of surface defects. This is a very complex matter, as there is a wide spectrum of defects which can be treated by means of grinding. Various applications of grinding may be superimposed. A combined treatment of different defects normally results in less work, as compared to the treatment of defects individually (expressed by the number of grinding passes required). Also, grinding will tend to minimise the need for other maintenance work. Hence, it is important to optimise grinding by carefully choosing the right timing.

It is necessary to look for that maintenance strategy which provides an overall optimum. Too much grinding is as harmful as too little grinding.

Any delay in carrying out rail rectification work results in additional defects, and therefore an increase in costs. Whereas, a too early intervention by means of grinding means high rectification costs. Thus, the use of in-track rail grinding should also be aimed at minimising costs.

Effects of rail grinding on the overall track structure and on the rolling stock

Rail grinding does not only optimise the condition of the rail, but also that of:

— *the overall track structure:* the condition of the rail surface has a considerable influence on that of the overall track structure. Corrugation in the longitudinal plane results in higher stresses for all track components. Rail rectification not only extends the service life of the rail but, as it reduces the dynamic loading on the entire track structure, it also leads to a reduction in the occurrence of damaged, and broken, fastenings and sleepers. It, thus, postpones the need for a premature replacement thereof.

Further, a timely removal of rail defects by means of grinding can lead to a reduction in the amount of tamping and ballast cleaning required. As noted earlier, rail defects lead to an increase in vibrations which, in turn, result in a more rapid deterioration of track alignment and geometry, as well as vehicle riding quality, which very often require remedying by means of tamping. Because of the subsequent ballast deterioration, premature ballast cleaning and replacement is necessary;

— *the rolling stock, incl. passengers and goods carried:* passengers and people living near railway lines are affected by the high levels of noise and vibration resulting from wheels running on an uneven rail surface. Thus, providing smooth running and good rail/wheel contact conditions by means of rail grinding contributes significantly to an improvement in ride quality and a decrease in noise and vibration levels.

Potential for further optimisation

Rail rectification is aimed at two targets: the extension of the service life of the rail, and the provision of optimal conditions in order to allow maximum traffic loads. The following potential for optimisation exists:

— *increase of wear limits:* for an optimum use of rail steel, an increase in the amount of permissible wear may be considered. With a careful treatment of the transverse profile by means of grinding, a smooth and even distribution of the forces and internal stresses can be ensured;

— *optimal intervention threshold:* maintenance work should be planned and executed at the right moment all round, whereby the operational side plays a decisive role. For instance, it is useful to grind new track prior to the opening of the line for traffic as thus, from a technical point of view, the best conditions for wheel/rail contact are provided. Also, from an operational point of view, it is preferable to work on a non-operational line as this allows a maximum exploitation of a grinding machine within a given work shift;

— *combination of grinding applications:* costs could be reduced by combining different grinding applications. For instance, in sharp curves, the high rail suffers from lateral wear, whereas the low rail is seriously affected by short-wave corrugation. Both types of wear could be rectified simultaneously by means of grinding. By simultaneously removing short waves on the low rail and applying asymmetric profiling to the high rail, curving forces and, thus, wear is reduced. If in doing so the service life of the rail is increased from an original five to say eight years, the financial savings would be considerable;

— *grinding in combination with other maintenance activities:* when considering track maintenance work in general, and tamping in particular, any combination with grinding can have positive effects. Simultaneous tamping and rail grinding is most efficient. Technically, the effect of tamping is highest when the running surface of the rail has no irregularities whatsoever, which would otherwise lead to vibrations which, as noted earlier, result in a fast deterioration of the track alignment back to its pre-tamping status.

Integration of rail grinding in the overall track maintenance strategy

It is often discussed, and sometimes already being practised, to integrate grinding in the overall track maintenance strategy, as there is a common understanding that rail maintenance reduces the amount of other track maintenance work required, and also contributes greatly to the reduction in the overall life-cycle costs of the track. At present, however, it is not yet possible to precisely prove the quantitative benefits thereof. Only simulation models could pinpoint the magnitude of potential savings which could be achieved in this respect. A useful verification can only be obtained by carrying out full-scale field trials along with ongoing observations.

Conclusions

Rail maintenance has a significant influence on the entire railway system. Its application has far-reaching effects on the financial and operational performance, as it contributes to:

— an increase in return on investment;
— an improvement in efficiency of the railway system;
— a reduction in operating costs.

Adequate rail maintenance requires a long-term strategy engulfing a number of different activities. The main issue is to find the ideal timing for intervention, which is in direct relation with the condition of the rail. In this respect, an optimally co-ordinated site management is as important as an optimised exploitation of the grinding trains. Only heavy-duty machines, operated with care and skill, can guarantee technically and economically good results.

In-track rail grinding is an indispensable means of track maintenance which, both technically and economically, contributes significantly to the optimisation of railway track.

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