Considerations regarding noise reduction by means of rail grinding

It is a well-known fact that by means of rail grinding, whereby rail head surface irregularities in the longitudinal plane, in particular corrugation, are removed and the transverse rail head profile is optimised, also a positive effect as regards the reduction of noise resulting from wheel/rail interaction is achieved. In this article, considerations are put forward, resulting from discussions conducted within the European Rail Maintenance (ERM) Group (an informal think-tank that was formed following the completion of the Innotrack project), as regards the possibilities and limitations of noise reduction by means of rail grinding.

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Railway operations generate noise as almost all means of transport do and, in a world that today is sensitive to environmental matters, railway noise is a very important and topical issue.

However, noise resulting from the passage of trains is a very complex matter, as it is influenced by various factors, such as (see also Fig. 1):
— the type of rolling stock operated (e.g. noise resulting from traction motors, pantograph/catenary interaction, air drag);
— the train operation itself (e.g. speed travelled, braking);
— the prevailing infrastructure (e.g. presence of bridges, level crossings, type of track structure adopted (e.g. sleeper type, slab track, switches));
— the maintenance status of the prevailing rolling stock and track.

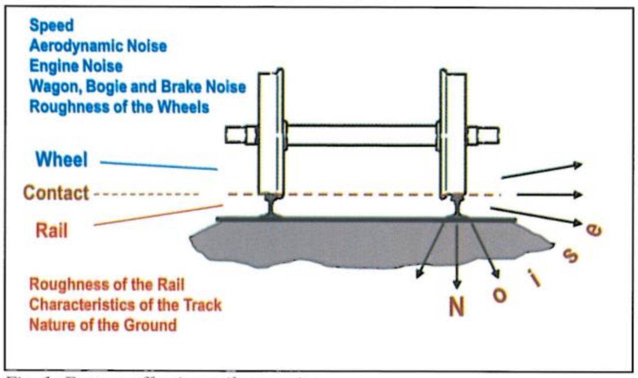

Fig. 1: Factors affecting railway noise

In addition, noise may emerge from wheel/rail interaction due to (see also Figs. 2, 3, 4 and 5):
— rail head surface irregularities in the longitudinal plane (e.g. corrugation, ballast imprints, squats, irregular welds, rail joints), which can be remedied by means of rail reprofiling;
— the shape of the transverse rail head profile, though to a lesser extent (e.g. at the gauge side of the high rail in curves);
— wheel running surface irregularities (e.g. out-of-roundness, flats, fatigue phenomena), which can be remedied by means of wheel reprofiling and the use of synthetic brake pads;
— wheel-flange contact with the rail, which can be remedied by means of lubrication and the application of friction modifiers on the running surface of the low rail in curves (a new method that is currently under development).

Fig. 2: Short-pitch corrugation

Fig. 4: Wheel running surface defects

Fig. 3: Short-wave corrugation

Fig. 5: Wheel flats

From the early beginnings of the adoption of rail grinding, it has been observed that the removal of rail head surface irregularities, in particular corrugation, also has a positive effect on the reduction of noise emerging from the wheel/rail contact area during the passage of trains. As a logical consequence, when complaints about noise from residents living near railway lines called for measures to be undertaken, rail grinding has often been proposed to improve the situation.

NOISE REDUCTION GRINDING

Often the term "acoustic grinding" is used when referring to the reduction of railway noise – resulting from wheel/rail interaction – by means of rail grinding.

However, as rail reprofiling is mainly aimed at re-establishing, as much as possible, the smoothness of the rail head surface in the wheel/rail contact area, it follows that rail grinding, per se, cannot achieve a specified or defined noise level. Therefore, it may be more appropriate to speak of "noise reduction by means of rail grinding", or in short "noise reduction grinding", as effectively the wheel/rail contact area is optimised in the course of maintenance grinding that – as a welcome consequence – also reduces the noise emitted at this critical area for wheel/rail interaction.

All that rail grinding – independent of the type of method or strategy adopted – can achieve is an even, corrugation and defect-free, well-positioned wheel/rail contact band that will provide a comparatively low – if not the lowest possible – noise level during wheel/rail interaction, as far as the rail head profile is concerned. However, the smoothness of the wheel profile is the other factor in the equation that needs to be taken into consideration – both the rail and wheel aspects should be regarded, in order to prevent an early recurrence of the problem. In this article, however, only the factor rail is addressed.

NOISE REDUCTION GRINDING – GEOMETRIC VALUES SPECIFICATION

Rail grinding work can only be specified by prescribing geometric values with respect to evenness, profile shape and surface roughness of the rail head, as well as tight tolerances regarding the amount of metal that needs to be removed (minimum and maximum metal removal rates) to achieve these values.

However, the often expressed wish to guarantee specific noise levels following grinding, and documentation thereof, is not possible in practice, as the noise recordings that would be needed for this, on the one hand, also would reflect track structure and train operating factors and, on the other hand, they cannot be conducted during or immediately following grinding. As a consequence, prescribing geometric values is the only adequate means to specify geometric rail rectification work, if also aiming at favourable noise reduction properties in the wheel/rail contact area.

When performing rail grinding that is also aimed at reducing noise resulting from wheel/rail interaction, there are a number of aspects that have to be taken into consideration, such as:
— the longitudinal rail head profile;
— the transverse rail head profile;
— the condition of the rail head surface.

The longitudinal rail head profile
As noted earlier, rail head surface irregularities in the longitudinal plane, in particular corrugation, and, to a lesser extent, the shape of the transverse rail head profile may result in the emergence of noise from wheel/rail interaction. Therefore, an evenness of the rail head surface following reprofiling is of major importance, as any remaining rail head surface irregularities may accelerate the recurrence of corrugation and, consequently, lead to increased noise levels again shortly after grinding. A correct specification for rail grinding work, and a subsequent execution thereof, can ensure the elimination of rail head surface irregularities in the longitudinal plane. In this respect, the acceptance criteria for the longitudinal rail head profile following grinding, as specified in European standard EN 13231-3:2012 [Ref.], should ensure that an acceptable low average noise level is achieved by means of grinding (Table 1).

Wavelength of rail head surface irregularity (mm)	10 - 30	30 - 100	100 - 300	300 - 1,000
Peak-to-peak limit value (mm)	± 0.010	± 0.010	± 0.015	± 0.075

Table 1: Acceptance criteria (peak-to-peak limit values) for the longitudinal rail head profile following grinding, as per EN 13231-3:2012 [Ref.]

It should be noted that EN 13231-3:2012 allows some percentage of the ground length to be outside the specified peak-to-peak limit values (see Table 2), either because they have a very different profile from the majority of rails on a given railway line (e.g. plug rails), or because they pose a problem for the adopted rail re-profiling technology (e.g. level crossings, clearance problems near signalling equipment because of the presence of axle counters, etc.).

Wavelength of rail head surface irregularity (mm)	10 - 30	30 - 100	100 - 300	300 - 1,000
Class 1	5%	5%	5%	5%
Class 2	N/A	10%	10%	N/A

Table 2: Percentage of ground length allowed to exceed specified peak-to-peak acceptance limit values for the longitudinal profile, as per EN 13231-3:2012 [Ref.]

The transverse rail head profile
The shape of the transverse rail head profile determines the width and position of the wheel/rail contact band on the rail head surface. Wide wheel/rail contact zones, which develop over time as a result of natural wear, provoke more friction movement in the wheel/rail contact band, which translates into increased noise levels. Usually, all specified target profiles for rail grinding work are designed in such a manner that geometrically optimal wheel/rail contact conditions are provided.

Thus, in general, when optimising the transverse rail head profile also the noise situation is improved.

The condition of the rail head surface
Another factor that is of major importance following rail grinding is the rail head surface condition, which is usually referred to as “surface finish”, whereby a distinction can be made between a fine (acoustic) finish, a rough (aggressive) finish, and a standard finish (see Figs. 6, 7 and 8).

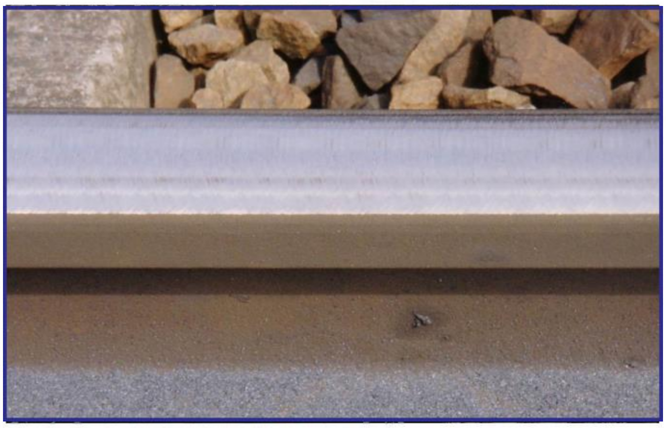

Fig. 6: Ground rail – fine (acoustic) finish

Fig. 7: Ground rail – rough (aggressive) finish

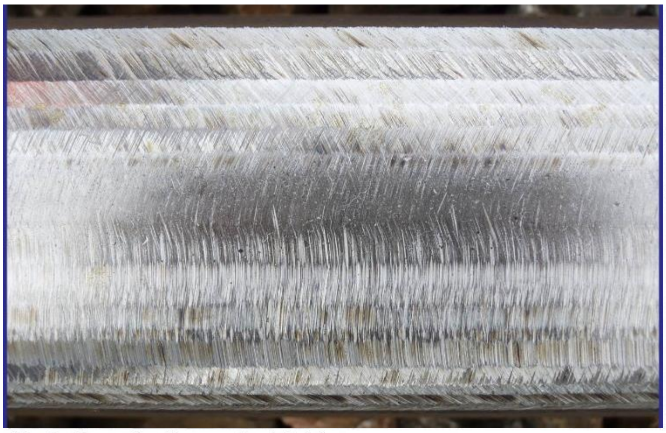

Fig. 8: Ground rail – standard finish

NOISE REDUCTION GRINDING – CONSIDERATIONS

Within the European Rail Maintenance (ERM) Group (an informal think-tank that was formed following the completion of the Innotrack project), discussions have led to a number of considerations with respect to noise reduction grinding, which are alluded to in the following.

Noise perception – a subjective matter
First of all, it should be noted that noise perception is a subjective matter, in that the same absolutely measured noise levels may provoke different reactions from different people.

Further, there is often a difference between what is legally permissible and what subjective perception considers tolerable. Sometimes, higher than permitted noise levels may be considered acceptable, whereas there may still be complaints from some persons about noise levels that are well within the legal limits. Consequently, it is very difficult to define specifications for noise reduction grinding that take into account both aspects – balancing measurable values and subjective judgement.

Temporary noise effect immediately following grinding

In general, a freshly ground rail head surface looks rougher immediately following grinding than it did before. As a matter of fact, the initial rail head surface roughness condition resulting from the grinding-stone action causes high-frequency noise during wheel/rail interaction, often referred to as "metallic noise" or "squealing". This particular noise, noticeable directly following grinding, diminishes over time, depending on prevailing track characteristics (e.g. track elasticity, rail hardness – harder rail steel grades do not wear as quickly as softer rail steel grades, in the latter case rail head surface roughness remains for a longer time period), as well as rail operation characteristics (e.g. type of rolling stock, speed, axle load).

In the case of heavy-haul railway lines, characterised by heavy axle loads, the passage of just a few long trains may make all grinding marks disappear, whereas in the case of conventional railway lines, this may be achieved after several days or weeks of train operation. In the case of light rail traffic (metros, trams), grinding marks may still be present even after some months, in which case measures to limit the effects of rail head surface roughness and waviness following grinding may be considered, e.g. the use of softer rail steel grades, lubrication, or the adoption of a particular grinding-stone pattern.

In Table 3, typical wavelengths of rail head surface roughness following rail grinding are shown for different grinding speeds.

Grinding speed (km/h)	3	5	6	8	10	15
Wavelength of rail head surface roughness following rail grinding (mm)	13.8	23.1	27.6	37.0	46.3	69.3

Table 3: Typical wavelengths of rail head surface roughness following rail grinding for different grinding speeds

Grinding application to remedy noise following grinding

Using conventional rail grinding technology with rotating grinding stones at a speed of < 5 km/h or > 8 km/h tends to result in lower noise levels following grinding. For productivity reasons, however, the first option is no longer used. The often proposed use of special grinding stones (e.g. featuring finer grit) has a negative effect on grinding production rates and logistics – the lower production rates and the considerably higher costs involved may not compensate the noise reduction that is achieved for just a comparatively short period of time.

Tailor-made grinding application in noise-sensitive areas

When performing rail grinding for reasons other than corrugation removal (that immediately results in noise reduction), sometimes negative acoustic effects are perceived, especially in the case of cyclic elimination or reduction of rolling contact fatigue (RCF), as the grinding activity itself may provoke complaints from residents living near railway lines. The reason for the temporary slight increase in noise levels may be due to the attempt, during rail grinding, to remove as much metal as possible within a specified low number of grinding passes (mostly just one or two). The resulting rougher rail head surface unintentionally increases the noise level in the more sensitive frequency zone. Thus, prioritisation of quantity over quality has a certain negative effect with respect to noise, which needs careful consideration.

Defining rail grinding specifications that satisfy everyone is never simple. Thus, in some instances (e.g. in noise-sensitive areas), it may be better to adopt tailor-made, locally appropriate grinding applications, which take into account that:

— the selected rail grinding strategy is compatible with the prevailing rail steel grade;
— the application of lubricants on the high rail in curves and friction modifiers on the rail running surface could also be considered, as these may also reduce noise levels;
— the specifications for rail grinding work – in particular with respect to frequency and metal removal rates, as well as rail head surface finish requirements per intervention, should be stringent;
— the lower production rates resulting from the tailor-made grinding application may result in higher costs.

FINAL REMARKS

Elimination of rail head surface irregularities, in particular corrugation, combined with optimised profiling of the rail head, leads to a reduction in noise levels resulting from wheel/rail interaction. Any additional grinding aimed at reducing the noise levels already achieved by a geometrically optimal situation regarding track maintenance is usually not beneficial. However, some exceptions, such as in the case of light rail transit lines and specific local conditions, may require special measures, as well as distinctive specifications for grinding work.

"Noise reduction grinding" is essentially accomplished by means of corrugation removal and corrective profiling work. Consequently, the commonly used technical term "acoustic grinding" should be reconsidered: typically, providing an even, defect-free surface and an appropriate transverse profile of the rail head grants a low noise level, on condition that the specifications defined in EN 13231-3:2012 are met.

Only in specific cases, particular specifications with related production effects may be considered. It is most important to respect a systems approach. In a multi-component environment such as the railway, each individual aspect contributes to the overall effect, whereby the most severe one dominates all the others. Therefore, optimising only one component may not be a successful approach. With respect to noise reduction, optimisation of the wheel/rail contact zone plays an important role, but it is not the only approach that should be taken into consideration.

Finally, any rail reprofiling activity aimed at lowering noise levels resulting from wheel/rail interaction contributes to an improved rail maintenance situation, as – in a reactive way – any rail grinding that is performed for maintenance reasons also helps to reduce noise radiating from the rail head surface to an acceptable level.

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