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Rail care – evolution and strategy

Grinding technology has been very significantly further developed in the course of the past thirty years. Grinding rails today can also be used as a means of delaying the formation of head checks. If the correct grinding strategy is adopted, it is possible to cut costs very considerably, while achieving an improved quality.

The technical term "rail care" means regular maintenance of the rail surface, mainly by grinding. The removal of material eliminates irregularities of the top surface, gives them back their level longitudinal profile and, at the same time, optimises their transverse section. This procedure ought to maximise the service life of the rail, when ensuring minimum necessary material removal rates. Given that the same material is used for plain rails and points, caring for them is the same in both situations. The technology used is the means to the end and for the purposes of this report. It includes both grinding trains and switch grinding machines (Fig. 1).

Fig. 1: Modern grinding machines of Speno International SA *(Source of all photos/drawings: Speno)*

1 Development of rail machining

Up until the early 1980s, the grinding of rails was limited to working on their longitudinal sections. The technique was used essentially to remove short-pitch corrugation and long-pitch corrugation, with the agreeable side-effect of reducing noise. Doing anything about the transverse section played only a minor role. Fixed grinding motors required a high number of grinding passes to complete a job. The low level of productivity in those days and the limited budgets available made grinding appear almost like an "exotic technology".

It was also the case up until the 1980s that it was the railway personnel who were responsible for performing and supervising the grinding work and therefore also for determining the grinding criteria and choosing the number of passes. The development of pivotable grinding motors gave a big boost to the productivity of the technique. Fewer grinding passes were needed for rails that had been run flat. Just improving the transverse section was considered to be enough, and a mere approximation, somewhat closer to the as-new profile, was regarded as adequate.

That was also the time when development work began on manual measuring devices for the transverse section, along with the grinding of rails making up pointwork, and when the discussion on target profiles and production tolerances started too. The computerisation of grinding machines was one of the major trends of the 1990s. Another was the appearance of high-performance machines permitting higher production outputs. In parallel, systems were developed

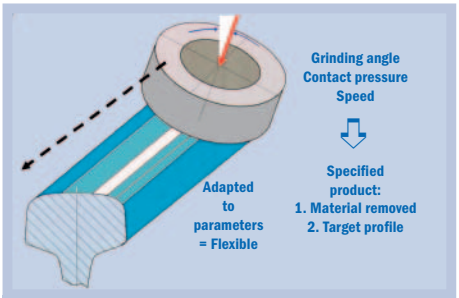

Fig. 2: Systematics of rail grinding

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Fig. 3: Running-edge fatigue

Fig. 4: Head checks on the running edge

for the continuous measurement of the transverse profile and these became integral components of the grinding machines. At last, the importance of the transverse profile came to be recognised, and corresponding specifications were introduced. The European standardisation body, CEN (Comité Européen pour la Normalisation), added grinding specifications to the subjects it dealt with (Fig. 2). More and more use was made of special target cross-sections. Today, it is taken for granted that grinding work must be executed to precise specifications and monitored by means of continuous measurement of both the longitudinal and the transverse profile and that this data must be documented for acceptance reports. The possible production throughputs of modern machines have increased still further, and, thanks to the fact that they can now work flexibly at different speeds of up to 10 km/h, new productivity records have been set. One of the latest further developments is that of testing devices using eddy currents for measuring the depth of fatigue cracks, and these have already been installed on several grinding machines.

2 Head-check grinding

The interaction between wheel and rail is essential for transferring loads and guiding trains. If the rails are given appropriate rail head profiles, wheel sets will be self-centring on straight tracks and will assume a virtually radial position in curves. To begin with, the targets set for "reprofiling" were thus close to the rolling-mill profile for a new rail within the range of –70° on the running edge and up to +5° towards the outer edge.

The contact zone of a rail is an extremely complex matter, since the leading and trailing wheel sets in a bogie touch different parts of the rail in curves and thus cause different "footprints" and stressed zones. This situation frequently causes excessive loads on the running edges (Fig. 3). Another widespread phenomenon is known as rolling contact fatigue (RCF), which quickly leads to the formation of cracks on the top surface of the outer rail, and these are widely known as "head checks" (Fig. 4). Their position, spacing, size, depth of penetration and inclination vary depending on the load on the material. Rolling contact fatigue is a very complex process.

Deutsche Bahn and Speno International joined forces to carry out a long-term test to look into possibilities for the efficient machining of areas at risk. Twenty test sections, each 100 metres long, were selected and each of these was equipped with two measuring points. The first test phase lasted from October 1996 until December 1999 and focused on selecting the ideal target profiles and favourable production tolerances for minimising the risk of the formation of head checks. It emerged that the standard target profile corresponded almost precisely to the profile resulting from wear, that minus tolerances were advantageous, whereas plus tolerances ought to be excluded. It was also observed that fatigue growth was less on head-hardened rails.

The second test phase lasted from January 2000 until April 2006 and was used to work out a favourable grinding cycle and the corresponding amounts of material to be removed. Various relationships needed to be considered: head-check growth and the development of wear, on the one hand, and the removal of metal and the grinding cycle, on the other hand. It is also necessary to take operational factors into account, such as time, costs and operational constraints.

The conclusion of this work was that, to begin with, the existing surface fatigue ought to be removed by corrective action. Thus the depth of metal to be removed from running edges must correspond to the defect depth (i.e. in the approximate range of 0.6–3.0 mm), and the maximum negative tolerance can be permitted to reach 1.0 mm. This should then be followed by various controlled actions. The depth of metal to be removed in the middle of the rail ought generally to be 0.1 mm, and the amount to be removed at the running edge ought to be 0.2–0.6 mm, corresponding to the depth of the faults. The researchers also made the proposal that the chosen target profile ought to be an anti-head-check one, corresponding to the 60E2 standard profile, with 0.6 mm under-grinding of the running edge. The production tolerance ought then to be laid down for the most demanding requirements and thus set at ± 0.3 mm.

Tests performed by other European railways on the subject of surface fatigue and their analyses of their results have led to similar conclusions. In the Netherlands, for instance, the infrastructure manager, ProRail, has developed a special target profile called "U54E1 AHC" (formerly UIC54), to be maintained by grinding in regular cycles (Fig. 5). The SNCF in France has specified two anti-head-check profiles with different details: "AHCP" (for preventive grinding) and "AHCC" (for corrective grinding). These also envisage cyclical grinding in future. In Austria, the Federal Railways (ÖBB) have developed a special profile, nicknamed "convex rail", to guarantee not only a low equivalent conicity but also a much-reduced formation of head checks.

3 Strategic direction

Faults in the top surfaces of rails are recurrent phenomena with far-reaching consequences for the interaction between them and train wheels (Fig. 6). That being so, it is only possible to make the most out of the strengths of grinding as a treatment if it is planned strategically and not just left to sporadic applications when particular needs arise.

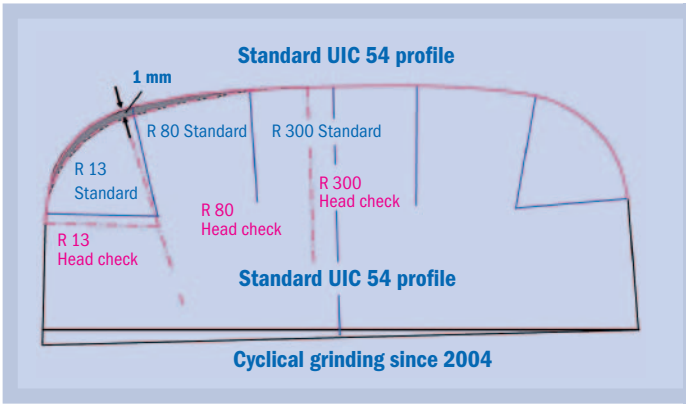

Fig. 5: Anti-head-check profile (ProRail)

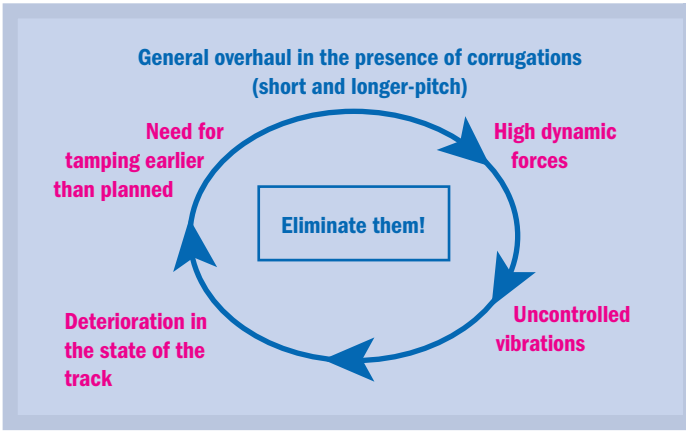

Fig. 6: Relationship between a general track overhaul and rail grinding

The available grinding strategies can be divided into three general classes:

- ▷ Preventive action: grinding before damage is discovered, for example the grinding of newly laid rails and cyclical grinding without measuring faults,
- ▷ Corrective action: removal of faults that have been measured as more or less severe, and
- ▷ Cyclically controlled action: removal of faults at an early (measured) stage while conditions are still optimum.

When corrugations (both short and long-pitch ones) are to be removed, it is common practice to measure the depth of damage for programming grinding actions. Railways practising this sort of strategy determine intervention thresholds, which trigger the machining of the affected sections of rails. If these limit values are adhered to strictly, the resulting work programmes will often be comprised of a large number of short sections to be ground, spread over considerable distances.

If the limit-values and the programming of grinding work are handled more flexibly in a broader maintenance context, money can be saved strategically. Especially when rails are suffering from corrugations (either short or long-pitch ones), any form of general overhaul planned for them ought always to be combined with grinding. The reason for this is that any unevenness in the running surfaces will still cause high dynamic forces and uncontrolled vibrations even after other operations have been performed and will soon contribute to a new deterioration in the state of the track, necessitating tamping earlier than otherwise planned.

It is especially in the machining of fatigue damage in the contact surface and the running edge that there is major potential for making savings through applying a strategically planned procedure. Modern grinding trains are able to make the most out of their big production capacity especially when they work on long uninterrupted sections. If grinding units are coupled together, it is possible to remove all the required amount of material in a single run, and top-performance machines are even able to achieve this at speeds of up to 10 km/h.

The three following examples have been selected in particular to show the possibilities opened up when a strategic approach is adopted for grinding.

Example 1:
When corrective grinding is performed a section at a time (with the removal of 0.3 mm of material from the rail head and an additional 1 mm from the running edge), a conventional RR32M grinding machine working on sections of 250 metres and making allowance for its turnaround and waiting times, manages to grind about 450 metres of track in one hour. If strategic planning achieves an increase the length of the grinding sections to 1000 metres, the same machine will grind 650 metres of track per hour, and the specific cost per metre will be correspondingly reduced.

Example 2:
If preventive grinding is performed in a broader maintenance context (removal of 0.3 mm over the whole of the rail head) a conventional RR32M grinding machine, working on 250-metre lengths, will process around 900 metres of track in one hour. If the lengths are increased to 1000 metres, its hourly throughput will already improve to 1300 metres. In this particular example, we see not only the effect of choosing longer lengths of track to be ground but, in particular, the advantage of performing preventive grinding – namely that it is possible to machine very considerably more sections of track spending less money on grinding.

Example 3:
The final example compares current grinding practice with considerations as to how the operation might be performed in future. With the current practice of moderate corrective grinding one 500-metre section at a time, a conventional grinding machine (RR32M) processes around 5840 metres of track in the course of an eight-hour shift. If a change is now made to continuous strategic grinding to maintain the quality of the rails (i.e. cyclical grinding after 60 million load-tonnes or at three-yearly intervals) and further assuming that the transverse profile is of a good quality and that 0.3 mm of material is to be removed, then two high-performance RR48M grinding machines coupled together working on unlimited lengths of track with just a single run are able to grind 31000 metres in a single eight-hour shift. The costs per metre (which recur every three years) are then only about 30% of those given for the previous example no. 2.

An alternative strategy in otherwise identical conditions might be to remove only 0.2 mm per grinding operation but to do this in a two-yearly cycle. The costs would be the same (since the distance processed per hour is greater if less material is removed), but the long-term quality (always having ideal rail-surface conditions) would be an additional gain.

4 Concluding remarks

Grinding technology has made impressive advances over the last thirty years. This has, however, been indispensable in order to be able to care for rails in a way that satisfies the ever more stringent demands. The dominant problem today is that of fatigue. The use of suitable target profiles and production tolerances is certainly one way of slowing down the formation of head checks, but the only way of really getting the problem under control is the strategic planning of grinding operations. When such plans are combined with the choice of the best grinding technology for the job-in-hand, it is also possible to save very considerable sums of money too.


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