Sustainable Maintenance of High-speed Lines With Mixed Traffic

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1. Introduction :

The classical ballasted track has, also for high-speed lines, not reached its physical limits. Numerous examples have proven this all over the world. Relatively low axle loads benefit the service life of tracks. When using the lines also for mixed traffic the superstructure design shall be in line to be fit for the higher dynamic loads coming from flatted wheels of cargo trains. To make ballasted track the most sustainable and most economical solution for high-speed lines with mixed traffic, the track materials chosen, and the track construction and maintenance works carried out must meet highest of requirements.

Aspects relevant to safety and availability require the highest level of process reliability to be ensured during the different stages of work. The track geometry should therefore be corrected on the basis of absolute coordinates, i.e. the exact target geometry of the track is re-established. Choosing the right tamping and consolidation parameters for track geometry correction and correctly shaping the rail head during rail treatment is essential. Preventive maintenance is to be targeted.

2. Maintenance of ballasted tracks starts with the correct design and construction

Maximum quality is crucial for the construction of new ballasted tracks. Numerous studies have shown that only the highest level of

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initial quality in the construction of new railway tracks ensures a long service of the tracks and, consequently, reduces the life cycle costs to a minimum.

This is why the track material must be treated, already during installation, with utmost care. The same quality requirements must be met when unloading and welding rails. For rail welding, uniform metallurgic quality, exact geometry of the rail surface and a highly compact heat-affected zone are of importance. Metallurgic transformation processes occur in the heat-affected zone when the welded rail cools down, which can affect the homogeneity of the rail. The flash-butt welding technology increases process reliability and reduces the heat-affected zone. It should be preferred over the alumino-thermic welding technology, especially on sections with highest demands of reliability, such as high-speed lines with mixed traffic.

Traction control systems of modern locomotives are using higher values of controlled slip. This leads to higher amount of rolling contact fatigue (RCF) defects on the rail, particular of head checking. To counteract RCF in curves the rail shall be chosen with higher rail grades. This is in line with a new UIC recommendation. Head hardened rails with Brinell hardnesses of 350 and more are performing much better in curves than standard rail grades of 260 Brinell hardness. On the other hand, it is still recommended to use the standard rail grades in tangent (better resistance against the rail defect type squats).

To improve the dynamic distribution of stresses, the track superstructure shall be well chosen. On high-speed lines with mixed traffic the rail profile normally has a weight of 60 kg per meter, such as the profile 60 E1). And, particularly on high-speed lines, elastic components are increasingly used on railway track. Elastic rail pads are used to protect the sleepers (leading to lower bending moments) and the ballast. Moreover, Under Sleeper Pads (USP) solutions are increasingly used. In particular, this applies to bridges, where the ballast would be subjected to overstressing without the use of elastic components. Both, soft rail pads and Under Sleeper Pads reduce sleeper voiding, a phenomenon that leads to a reduction of the lateral track resistance, in particular at transition zones besides bridges. Sleeper voiding also increases the dynamic loads in the ballasted bed.

When installing the ballast bed on high-speed lines, the ballast consolidation must be as high and homogeneous as possible. Therefore, the ballast bed must be consolidated in layers. The track maintenance machines used for this purpose must meet the highest of requirements regarding both quality and process reliability. Asphalt track-bed layers are increasingly installed underneath the ballast bed. This results in an improved load distribution and, crucial to sustainability, ensures improved drainage, as well as the complete sealing of the substructure protecting it from plant growth that reduces the service life of the ballast bed significantly.

In recent years, the above measures made ballasted track stand out due to its high quality. In the wavelength range of 3 to 25 m (as per D1 of EN13848), an initial quality regarding the standard deviation of the longitudinal level of between 0.25 and 0.3 mm can be reached when all relevant quality measures are applied. The high level of initial quality also extends the intervals between maintenance operations. Intervals between tamping operations in the respective track sections are between 100 million and 150 million gross tons, sometimes even more. To ensure maximum sustainability, the high quality of the track geometry must therefore be maintained in the correct manner. The maintenance strategy should take this into account.

3. Requirements to be met by the track geometry quality

Track geometry correction

High-speed tracks require a sustainable maintenance strategy. This is the only way to sustainably and reliably ensure maximum track geometry quality. Therefore, track sections must be maintained in cycles. High-capacity tamping machines are used for several reasons: Only high-capacity tamping machines can achieve the output required in short night-time track possessions. High-capacity tamping machines are operated in continuous working action. This results in a high track quality. In addition, the simultaneous tamping of several sleepers increases the track quality. This is why 09-3X and 09-4X tamping machines are mostly used on high-speed lines today.

A high level of process reliability is crucial to track geometry correction. Tamping parameters such as tamping pressure, squeeze times and tamping depth are therefore selected with utmost care. Quality recording systems make it possible to document all quality-related parameters.

Tamping machines allow a high track geometry quality to be achieved. In addition to realigning and tamping the track, optimum spatial consolidation of the ballast is important. The dynamic track stabilizer ensures this. It places the track in horizontal oscillations, performs a spatial re-consolidation of the ballast bed and increases the sustainability of the tamping operation. However, there is more that makes the dynamic track stabilizer essential: The track's resistance to lateral displacement (the "lateral track resistance") is reduced by around 50 % as a result of tamping. The dynamic track stabilizer increases the lateral stability significantly (plus 40 % against the value after tamping).

Absolute correction of the track geometry

Producing and maintaining the right track geometry quality on high-speed lines is of importance. Apart from choosing the right tamping parameters, and the spatial consolidation of the ballast bed using the dynamic track stabilizer, as described above, it is essential to restore the original target geometry of the track skeleton. A relative correction of the track geometry, as performed sometimes on conventional tracks, does not yield the desired results on high-speed lines. Due to the high travelling speeds of up to 300 km/h, which is equivalent to 80 m/s, long-wave track geometry faults must be taken into consideration. With relative track geometry correction the focus is placed on the correction of short-wave faults of up to approx. 50 m. Therefore, this relative correction method is not suited for high-speed lines. The objective must be to restore the absolute track geometry quality. Only then the track geometry faults affecting the ride comfort (up to 200 m approximately) can be corrected. State-of-the-art measuring systems provide support for absolute surveying and controlled lifting and aligning during tamping.

Ballast bed cleaning

Only in good ballast conditions can a sustainably high level of track geometry quality be ensured. Therefore, the ballast bed must be renewed over time. For this purpose, ballast cleaning machines are used. The principles applying to this maintenance measure are similar to the ones applied to track geometry correction using tamping machines. A long service life is only achieved if maximum initial quality is produced during the installation of the ballasted tracks.

Various parameters influence the service life of the ballast bed: load tons transported, line speed, ballast stone composition, hardness of the ballast, rail welding quality and rail treatment strategy. However, another major parameter is the axle load. Low axle loads enable ballasted high-speed tracks to reach long service lives of 30 years and even more, although one might think that the resulting higher vertical dynamics in high-speed-lines would cause the classical ballast bed to reach its physical limits. The worst circumstances regarding service life of the ballasted bed are: higher axle loads, stiff subsoil, concrete sleepers with stiff rail pads and flatted wheels (of loaded cargo trains).

When ballast condition becomes poorer the phenomenon of sleeper voiding increases, leading to so-called “white spots”. Especially on transitions next to bridges voiding might lead to reduce the lateral track resistance significantly. At least on bridges and respective transitions soft rail pads shall be installed to reduce sleeper voiding.

If ballast cleaning is required on high-speed lines, high-capacity ballast bed cleaning systems are almost exclusively used due to the respective availability requirements. A uniform and spatial compaction of the ballast is necessary for reaching a sustainable track quality.

Some machines are even able to perform ballast bed cleaning and track renewal in one pass. Special ballast cleaning machines for turnouts were designed for the fast treatment of turnouts. These machines make it possible to clean the ballast bed without preparation, in particular without cutting the turnouts, which was required until only recently.

4. Requirements to be met by aerodynamics

The role of aerodynamic aspects for the operation of high-speed lines has increasingly gained importance. Pressure variations in tunnel areas must be taken into consideration when designing tunnel crosscuts. For train traffic on the classical ballasted track, it is important that the sleepers are free from ballast stones. If not, the dynamic pressure peaks resulting from train traffic start to move the ballast stones. When hit by these stones, other ballast stones are swirled up. The phenomenon is called "ballast flying". Therefore, it is indispensable to sweep the ballast bed after track tamping, with the surface of the ballast bed ending a few centimetres underneath the upper edge of the sleepers. Recently, however, tests have been carried out with sleeper surfaces that prevent ballast stones from lying on them. The design of the cars shall prevent ice falling in winter.

5. Requirements to be met by the rail/wheel contact

The quality of the riding behaviour of trains on high-speed lines is a complex interplay of vehicle and track, subject to diverse factors: The maintenance of tracks, particularly when it comes to rail treatment, must meet the highest of requirements, as deviations of only tenths of millimetres greatly affect the running stability of the vehicles. The exact track gauge, the right level of rail inclination and the right shape of the rail head are essential to achieve the correct wheel-rail parameter equivalent conicity. The shape of the rail head shall be well designed to establish the perfect rail/wheel contact. If the riding behaviour is still unstable, infrastructure operators and railway transport companies must carry out a joint investigation. Because of the important role of this topic, the respective investigation and improvement procedure is stipulated in detail by the Technical Specification for Interoperability (TSI).

Preventive rail treatment strategies based on the results of eddy current testing of rails are used world-wide to tackle head checking of rails.

6. Summary

The end of the classical ballasted track is still not even in sight. This is particularly true for high-speed lines. When it comes to operate high-speed lines with mixed traffic the track materials chosen and the track construction and maintenance works carried out must meet high requirements. When these requirements are met, the classical ballasted track not only involves the lowest installation cost but also the lowest life cycle costs. Numerous examples have proven this all over the world. In terms of sustainability, particularly on high-speed lines, ballasted track is still the best solution. A condition based preventive maintenance strategy is to be targeted. Therefore the role of measurement cars dealing with data and information is significantly increasing in the last years.