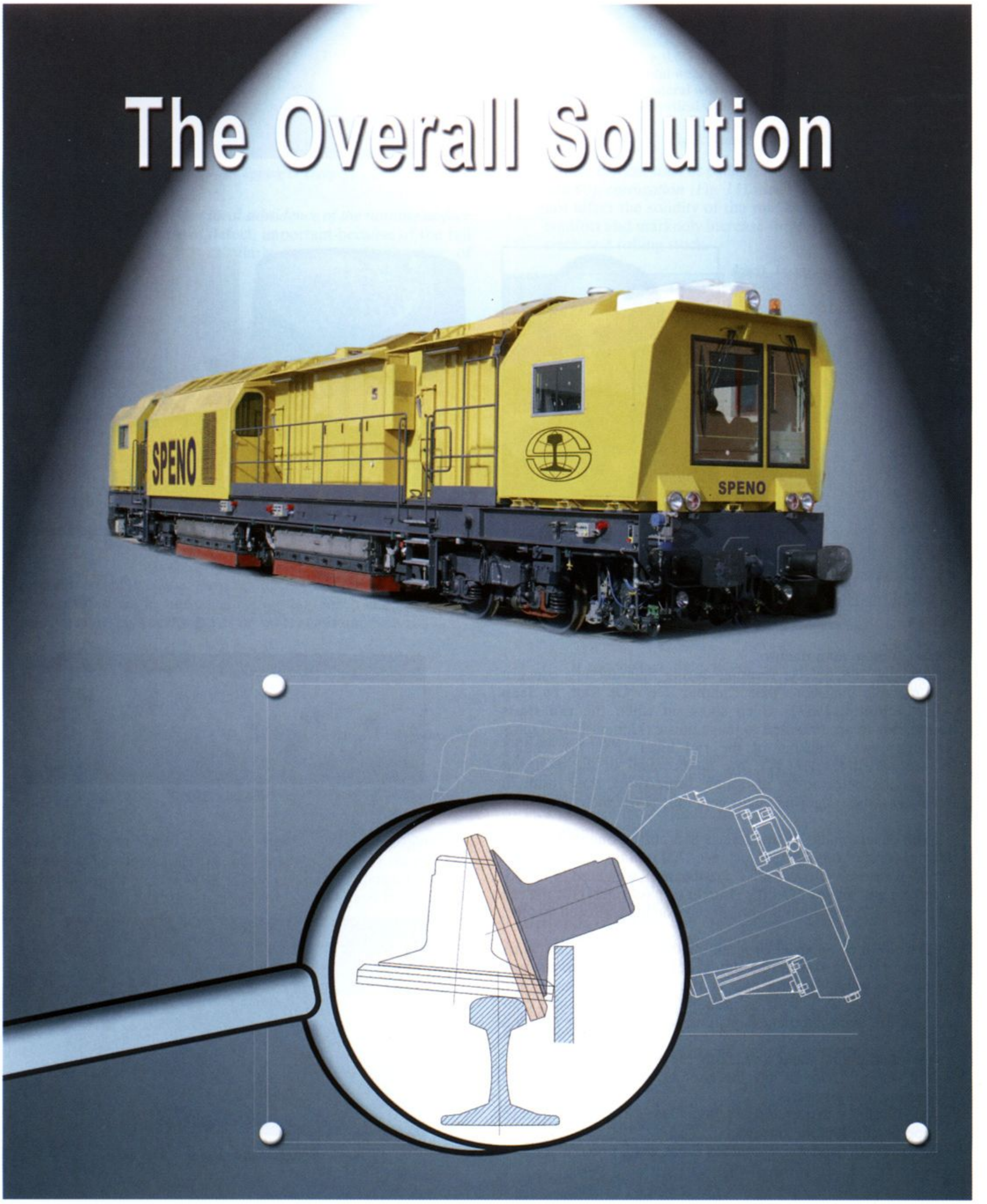
RAIL ENGINEERING INTERNATIONAL



The necessity of rail maintenance and track design considerations

In this article, the author, who has devoted nearly 50 years, both in and outside France, to serving the railways, draws the attention of both railway track owners and manufacturers to the technical and economic need to place rail inspection and maintenance during the service life of rails into the perspective of the design of the track, so that rail maintenance which, in any event, is indispensable, does not cripple network operation. Thus, besides examining rail defects and maintenance aspects, this article also looks at track structures and in-track equipment that may influence rail inspection and maintenance.

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RAIL DEFECTS

The rail is an essential track component which, thanks to technological progress, has a long service life. However, increased traffic volumes, axle loads and speeds place growing demands on the rail. The ideal for those responsible for rail maintenance would be for all rails of the same age, laid on a same section of line, to show signs of wear and/or deterioration in an identical manner and not to require replacement before the next renewal. In practice, however, it does not happen this way: some rails deteriorate prematurely, leading to isolated repairs and withdrawals from service.

Defects due to manufacture

Principally, rail defects forming during manufacture concern non-metallic inclusions (see Chapter 7 of 'Le Rail' by Jean Alias, Eyrolles, 1987), which show up when the rail starts to age, due to accumulated tonnage borne (kidney-shaped flaws or progressive cracking of the rail head (Fig. 1)). Failing preventative treatment (i.e. the replacement of the damaged rail section detected by ultrasonic inspection), they result in breakages, the triggering factor generally being the cold.

The development of the defects is of an exponential nature, from a certain tonnage: for instance, 700 million tons (fictional tonnage entered into the UIC classification, weighted by speed, axle load and nature of traffic (freight or passenger)) for the rail of type 60 E1. This limit is lower if the axle loads exceed 20 tons.

Despite technological progress made during the past years with respect to in-track rail welding, defects of alumino-thermic or electric welds are still one of the principal causes of rail breakage (Fig. 2). As far as alumino-thermic welds are concerned, the main anomalies encountered during their creation are:

— the overall time spent on making the weld is too short;
— not enough time is left for cooling between casting and putting into service;
— no grinding is carried out to trim off excessive metal, prior to opening of the line to traffic;
— difficult atmospheric conditions (heat, cold, rain).

Fig. 1: Example of a kidney-shaped flaw or progressive transversal cracking, of internal origin

Fig. 2: Example of a weld breakage

Defects due to wear

With respect to defects resulting from wear, a distinction can be made between:

— *fatigue defects due to wheel/rail contact:*
— *head checks - spalling of the gauge corner (Fig. 3):* this type of defect occurs on the gauge corner of the outer rails in curves, sometimes even on straight track and in crossings;

Fig. 3: Head checks

— *plastic deformation due to a false flange or hollow wheel treads (Fig. 4):* the false flange causes a continuous plastic deformation zone on the head of stock rails in switches and of wing rails in crossings;

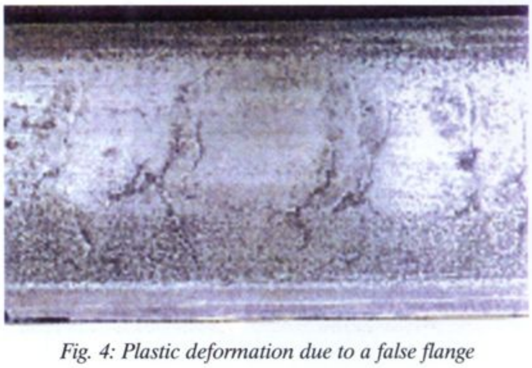

Fig. 4: Plastic deformation due to a false flange

— *tongue lipping - creep and vertical wear (Fig. 5):* this type of defect degenerates into cracks that progress almost horizontally under the surface of the rail head. Furthermore, multiple cracks can develop vertically, thus creating a rail breakage risk;

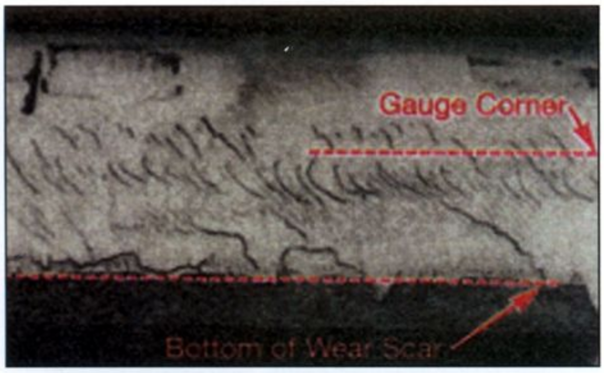

Fig. 5: Tongue lipping or creep

— *squats - cracking and local subsidence of the running surface (Fig. 6):* this type of defect, important because of the rail breakage risk, is particularly dangerous in the case of heat-treated rails;

Fig. 6: Squat: cracking and local subsidence of the running surface

— *gauge corner shelling (Fig. 7):* this type of defect generally affects the high rails in curves;

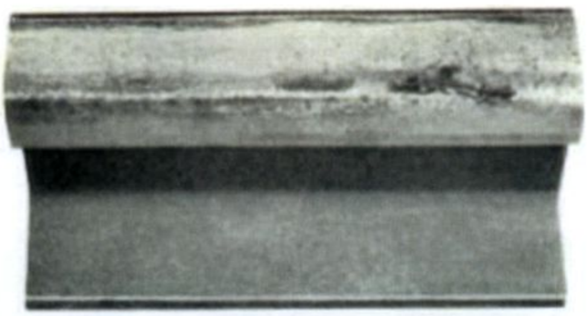

Fig. 7: Gauge corner shelling

— *other defects:*

— *lateral wear (Fig. 8):* this type of defect shortens the service life of rails in curves by about a third and, in some conditions, even by half, as compared to rails in straight track;

W = LW + 0.6 VW, where:
W is the total wear (mm)
LW is the lateral wear of the rail head (mm)
VW is the vertical wear of the rail head (mm)

Fig. 8: Lateral wear

— *surface defects, such as ballast and wheel-slip marks (Figs. 9 and 10), corrugation (Fig. 11), etc.:* these types of defect do not affect the solidity of the rail, but influence passenger comfort and markedly increase the cost of maintenance of track and rolling stock.

Fig. 9: Ballast marks

Fig. 10: Wheel-slip marks

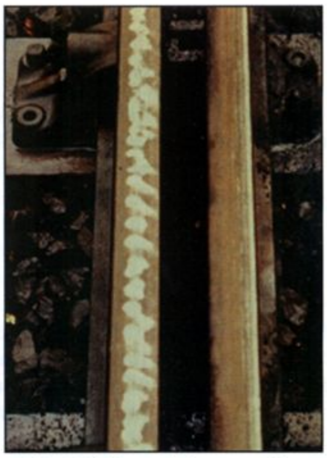

Fig. 11: Short-pitch corrugation

If the surface defects are very pronounced, they can, for this reason, lead to a premature withdrawal of the rail from service.

Rail ageing factors

Factors accelerating the ageing process of the rail include:
— the traffic carried (accumulated tonnage borne);
— climatic conditions;
— lack of preventative treatment;
— the extent of sinuosity of routes.

RAIL MAINTENANCE

Rail maintenance embraces the following tasks:
— detection of defects and forecasting of work;
— execution of the work required during scheduled track closures.

Inspection of rail condition has always been a constant preoccupation of track engineers. Different studies on the subject have shown that:
— the first rail defects of metallurgical origin appear when the accumulated tonnage borne is in the order of 100 million tonnes, sometimes less;
— the propagation of a rail defect due to wear (increase of its surface) is an exponential function of the traffic carried by the rail;

— the probability of a rail breakage due to defects is a normal law of average $S_r = 0.57.S_c$ and of deviation type $\sigma_{sr} = 0.18.S_c$, where:
S_r is the surface of the defect at breakage;
S_c is the surface of the rail head.

It is, therefore, important to regularly carry out non-destructive rail inspection, as well as periodic visual inspection.

Rail maintenance work (reconditioning by means of arc welding, grinding, temporary fish-plating, replacement of isolated rails, etc.) should be consistent with the possibilities offered by the operation of the line and controlled within the normal time limits granted.

Wear in the wheel/rail contact area and preventative maintenance

Today, it is known that wear in the wheel/rail contact area can manifest itself in the following different forms:
— head checks;
— tongue lipping (creep);
— squats.

As soon as these defects appear on the surface of the rail head, they can propagate in depth to such a degree as to bring about a breakage of the rail, unless something is done fairly rapidly.

It is of great importance that, as soon as possible after the rail has been laid, preventative maintenance, i.e. rail grinding, is carried out, in order to avoid the development of squats or head checks, thereby eliminating incipient micro-cracks even before they become visible. Grinding should then be carried out regularly to safeguard the rail against the occurrence of the aforementioned defects.

If a crack is visible (notably in the case of head checks), it is generally too late to eliminate it altogether and in an economical manner. When the cracks have a visible length of less than 15 mm, rail grinding is necessary to save the rail. The aim is not to eliminate the cracks, but to move the wheel/rail contact area away from the cracked zone. When the cracks are longer than 15 mm, measures must be taken to replace the affected rail.

Creep should be treated by means of grinding as soon as it appears, in order to eliminate any underlying cracks that may be present.

The case of heat-treated rails

On a number of railway networks, rail sections made of heat-treated steel blends, such as 350 LHT or 350 HT of the European standard, are used, particularly for switches. In this case, even greater attention should be paid to the state of the running surface, in order to appreciate, identify and check the effects of fatigue caused by wheel/rail contact. The development of head checks and squats can be formidable, especially in not regularly maintained parts of switches. For these rails, even more than for those of non heat-treated steel blends 700 or 900 N/mm^2, preventative grinding should be an imperative rule of maintenance and repeated as often as is necessary.

Requirements vis-à-vis track fastening systems

Rail maintenance can encounter difficulties due to features of the track fastening system used. Simplicity of the track fastening system is a determining factor as regards economy in rail maintenance. The track fastening system should make it possible to replace the rail rapidly and, in addition, remain impervious to the action of flames, particularly in a tunnel.

In Figs. 12, 13, 14 and 15, a number of track fastening systems are presented, the design of which poses no hindrance to rail maintenance.

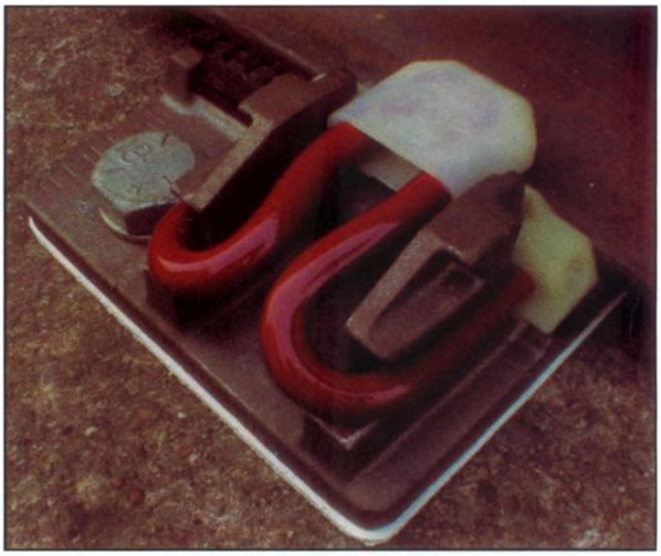

Fig. 12: Pre-assembled Pandrol FASTCLIP system

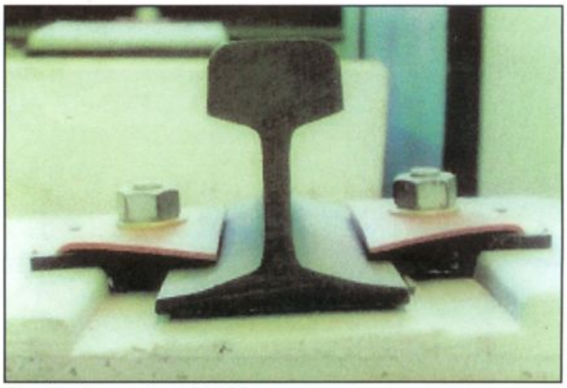

Fig. 13: Conventional Nabla system

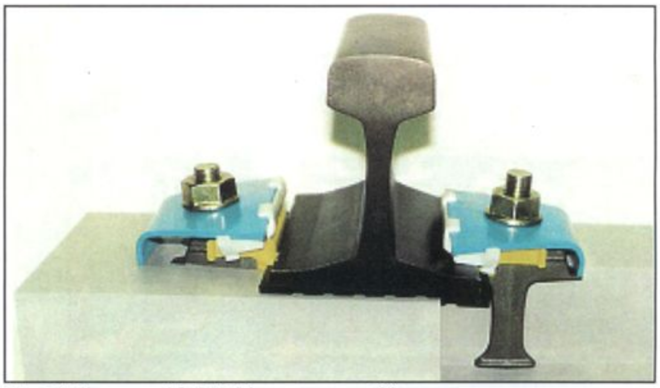

Fig. 14: Pre-assembled Nabla system type C8

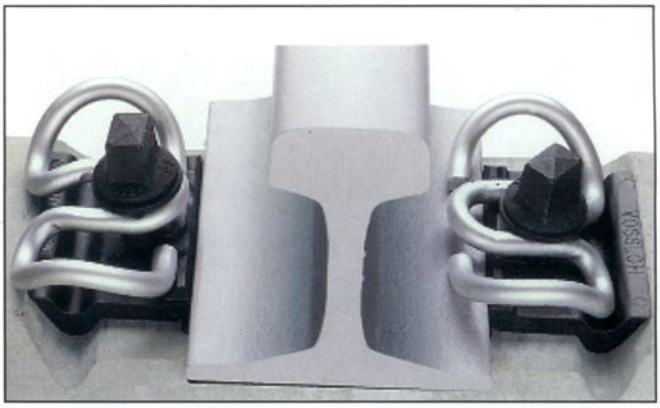

Fig. 15: Pre-assembled Vossloh SKL 14 system

Track structures with noise and vibration reduction features
During the past two decades, legislative and statutory regulations in the realm of environmental issues, particularly in Europe, have led railway infrastructure owners and manufacturers to introduce innovations in track design that significantly reduce the levels of noise and vibration resulting from the passage of trains. However, these sometimes involve designs that make rail maintenance difficult (e.g. when the rail is embedded or has anti-vibration features attached to it).

It is, therefore, of great importance that track structures with noise and vibration reduction features are designed in such a manner that they allow rail maintenance to be carried without difficulty, so that the rails can be repaired according to the book.

Constraints encountered with respect to maintenance of rails in mixed-gauge track
There are only a few countries worldwide where track featuring more than two stretches of rail, i.e. mixed-gauge track, can be found.

The principal countries outside Europe where mixed-gauge track can be found are:
— Brazil (1000/1600 mm);
— Australia (1067/1435/1600 mm);
— Tunisia (1000/1435 mm);
— Japan (1067/1435 mm).

In Europe, the following cases are worth mentioning:
— in Spain:
  — a trial track between Pozal and Gallinas (1435/1668 mm), which is operated at a speed of 240 km/h (Fig. 16);
  — two lines from Irun and Port-Bou to the border with France (1435/1668 mm), which are operated at low speeds;
— in Greece: an about 36 km line (1000/1435 mm) between the oil refinery of Elefsis and the port of Piraeus.

Fig. 16: Spanish double-gauge trial track

When maintaining rails in mixed-gauge track constraints can be encountered with respect to:
— *rail welding:* in the case of, for instance, the 1435/1668 mm double-gauge track, it is not possible to use hydraulic tensioning devices, whatever their type may be, due to the limited space between the two closest stretches of rail;
— *the track fastening systems:* bearing in mind the limited space between the two closest stretches of rail, it is preferable to choose a track fastening system that takes up a minimum of space. In Fig. 17, an example of such a system is shown;

Fig. 17: Example of a fastening system taking up little space (DSA fastening system of Railtech)

— *rail grinding:* experience gained in Japan (JR East) on an 87 km double-gauge track between Fukushima and Yamagata, put into service in 1992/1993 and used for mixed-traffic operation at a maximum speed of 130 km/h, has shown that there is no procedure for avoiding "overgrinding" of the rail shared by both the 1067 mm and 1435 mm gauges.

As regards the double-gauge track in Spain, the two rails corresponding to the 1435 mm gauge can be reprofiled entirely, whereas that of the 1668 mm gauge can only be reprofiled partially, the grinding units being limited to 42.5° (see Fig. 18).

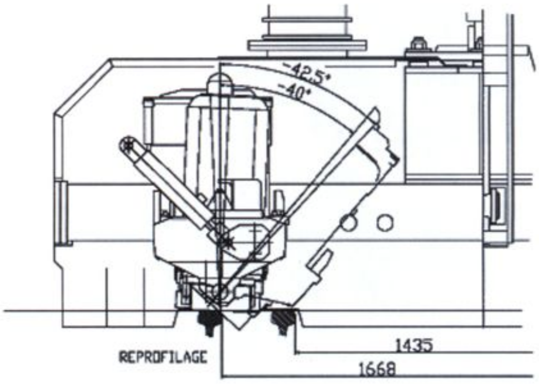

Fig. 18: Positioning of rail grinding unit for reprofiling rails in a 1435/1668 mm double-gauge track

Completely reprofiling the mixed-gauge track in Spain could be effected, though at a considerable expense, either:
— by using a rail grinding train for switches featuring a 1668 mm gauge; or
— by modifying the structure of an existing rail grinding train.

Rail reprofiling and all other maintenance work can prove even more complicated in the case of crossing bridges, if the mixed-gauge track is protected by safety rails aimed at limiting the consequences of a derailment.

Track-mounted equipment that can pose a hindrance to rail maintenance
Rail maintenance may be faced with difficulties due to track-mounted equipment, which may be installed:
— on the shoe of the rail;
— between the rails, but not on the sleeper(s);
— between the rails, on or in the sleeper(s);
— outside the running rails;
— along the track, in the open air or in a tunnel.

Track-mounted equipment requiring special precautions during rail maintenance mainly concern:
— signalling and telecommunication equipment;
— axle counters;
— measurement sensors for hot-box and wheel-flat detectors;
— cable paths.

For the entire gamut of sensors, and signalling and telecommunication equipment, random shocks and vibration should not adversely affect the working of these installations. Therefore, in most cases, the installations have to be dismantled and placed temporarily out of service while rail maintenance is being carried out.

Other objects that could pose a hindrance to rail maintenance include:
— *safety rails:* these are aimed to limit the transversal movement of vehicles, in the case that one or several axles might be derailed. The safety rails may have to be removed to allow the rail grinding train to carry out its work.

On French National Railways (SNCF), care has been taken to leave sufficient space (360-370 mm) between the foot of the safety rail and that of the running rail, so that track maintenance (tamping and grinding) can be carried out without having to remove the safety rails (Fig. 19);

Fig. 19: SNCF RER line C - active guard rail and safety rail

— *expansion joints:* the expansion joints for structures such as bridges and tunnels that have been designed in France, and put into service from 1993/1994, do not pose any difficulties in carrying out maintenance work. However, earlier designs present a double "flangeway", which limits the possibilities of rail grinding (see also Figs. 20 and 21).

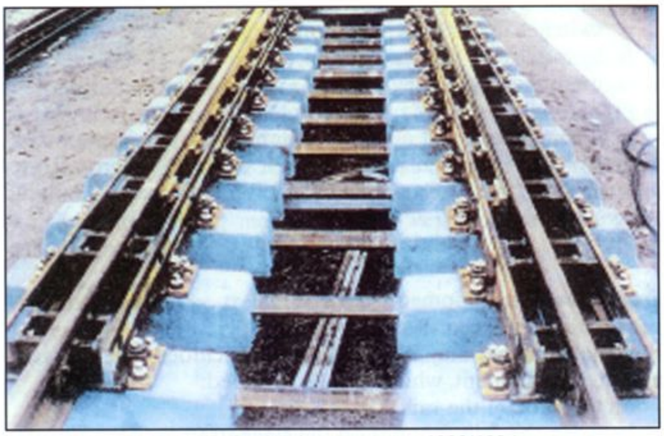

Fig. 20: Expansion joint, SNCF design prior to 1993/1994

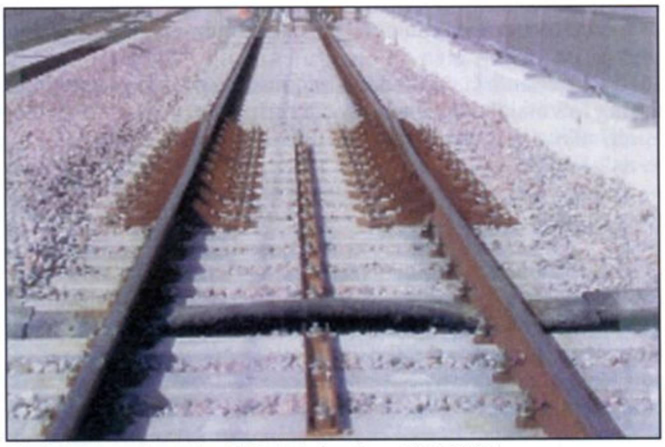

Fig. 21: Expansion joint, SNCF design from 1993/1994

The particular case of third rail power supply
Maintenance work of track featuring third rail requires the use of specially insulated equipment and safety measures, in order to protect staff.

Level crossings
During track renewal or geometry correction work, the unloading of ballast, particularly at level crossings, can result in flaws and wheel-slip marks, caused by the work trains and the road vehicles, which tend to deteriorate rapidly if they are not eliminated by means of rail grinding.

The diversity in level crossings worldwide (wooden, concrete or rubber planking; roadway in earth or in bituminous concrete with guard rails; etc.), the variable width of the flangeways, and the ease or difficulty of dismantling the planking, result in rail grinding trains experiencing more and more difficulty in meeting the requirements of high productivity in treating rails at level crossings, if the client network does not want to dismantle the planking to allow undisrupted operation.

MAINTENANCE METHODS: A SELECTION

Whatever the progress achieved to diminish rail wear, the rail carries loads in a repetitive manner and, consequently, the occurrence of surface defects and/or fatigue is unavoidable after a certain number of cycles. To this end, maintenance methods, which make it possible to extend to the maximum the service life of the rail remains economically necessary, and should be sufficient to meet the objectives of reliability and safety of network operation.

Rail maintenance embraces the following tasks:

— *detection of defects and forecasting of work by means of:*
  — visual observation during routine track inspections, on foot or by train-mounted inspection equipment, aimed at drawing up records to aid the planning of maintenance operations;
  — ultrasonic rail testing during periodic network inspections (Fig. 22), aimed at:
    — classifying rails according to network procedure;
    — programming protective measures;
    — consolidating data and plan any repairs required;
  — measuring and recording of surface defects (Fig. 23), such as corrugation, ballast and wheel-slip marks, and any other damage, aimed at scheduling preventative or corrective rail grinding, and reconditioning of rails by means of arc welding;

Fig. 22: Speno US2 ultrasonic rail testing car

Fig. 23: Measuring and recording of rail surface defects

Fig. 24: Rail grinding

Fig. 25: Rail lubrication

Fig. 26: Rail sawing

Fig. 27: High-pressure washing of rails

— *execution of maintenance and repair work required during scheduled track closures, such as:*
- — rail grinding (Fig. 24), whereby the following distinction can be made:
  - — initial grinding, which is aimed at:
    - — removing the decarbonised layer of newly laid rails;
    - — improving the longitudinal and transverse rail profile;
    - — eliminating residual defects from straightening (welds), of the surface (rolling defects), and of the profile or gradient (manufacturing tolerance);
  - — preventative grinding which, carried out periodically, is necessary before defects occur that might jeopardise track quality and the service life of the rail and, even, cause noise due to wheel/rail contact (protection of the environment);
  - — corrective grinding, which is aimed at removing defects that appear during the service life of the rail, such as flattening of the running surface, head checks and/or incipient squats, shelling, ballast and wheel-slip marks, etc.;
- — lubrication of rails in tight curves, using train-mounted or in-track lubricators (Fig. 25), or both, in order to avoid lateral rail wear;
- — reconditioning of the rail by means of arc welding, aimed at treating rail surface damage that cannot be eliminated completely by grinding (severe wheel-slip or ballast marks, periodic punching resulting from hard foreign bodies encrusted in a wheel, butts of used rail, etc.);
- — rail welding, in order to:
  - — replace a damaged section of rail. This is effected by sawing off the damaged section (Fig. 26) and welding in a new piece of rail;
  - — replace a glued insulating joint;
  - — repair a damaged or broken arc or alumino-thermic weld, whereby the following methods can be employed:
    - — repair by means of a single weld (normal or wide) or two welds (normal and/or wide);
    - — repair by inserting a new section of rail;
- — partial or complete replacement of a rail;
- — high-pressure washing of rails (Fig. 27), aimed at removing compost stuck to the running surface of the rail (carried out in areas where falling dead leaves form a risk, in order to avoid wheel slip and a lack of grip when braking).

CONCLUSIONS

Deterioration in rail condition is, to a large extent, due to fatigue or damage, whether the track is ballasted or not. Rail defects that are minor in appearance can lead to serious consequences that jeopardise a normal operation of a network. The manner in which the engineer approaches the deterioration in rail condition is similar to that of a doctor in relation to his patient. It involves the observation of the illness, the diagnosis and the remedy, as rail maintenance depends on:
- — visual and ultrasonic inspection
  (discovery of the deterioration and diagnosis);
- — standard maintenance (choice of treatment).

Moreover, the utmost attention has to be paid to prevention of the illness which, in the case of rail maintenance involves preventative grinding. Rail replacement only becomes necessary either when the rails have reached their wear limit, or when preventative withdrawals or breakages jeopardise a normal operation of the line.

When designing track structures, it is advisable to take into account that the rails can be repaired as easily and conveniently as possible, and in as short and few track possessions as possible. In this respect, when selecting a track structure, the following factors should be taken into account:
- — the irreversible character of the options chosen;
- — its level of sensitivity to geometry correction, welding, grinding (sparks) and reconditioning by means of arc welding (preheating temperature of the rail);
- — costs for repairs and breakdown service;
- — the ease or difficulty of their maintenance and the inherent costs;
- — their suitability for railway transport with respect to reliability and safety of operation.

If one is not careful, ignorance of the maintenance requirements can lead to track designs, the maintenance of which is incompatible with a normal operation of the line. Thus, the overall cost of owning a railway infrastructure can be greatly reduced when the maintenance factor is provided for from the outset. In other words, the engineer who designs the track should think of the engineer who has to maintain it.

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