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MODERN SOLUTIONS FOR RAIL ROLLING[1]

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Abstract

In recent years, high-speed rail transportation has been gaining interest over air transportation, for short and mid-distances, in terms of convenience and cost-effectiveness. Forecasts indicate that while this trend started in Europe and Far East, it will likely be followed by other regions of the world as well. All components required by high-speed railways are subject to stringent quality requirements, which directly affect the rail manufacturing process in particular. At the same time, the need for trasporting heavier payload on freight trains is also posing the necessity of improving the rail characteristics. Also for rail manufacturing, the globalization trends are forcing the steel industries towards modern production concepts. Flexibility, quality and operational profitability are regarded with increasing attention. Siemens' solutions for rail rolling are presented, with particular regard to the longer rails (e.g. 100 m) which offer market and cost advantages, but may pose layout problems for existing installations.

Key words: Rails; Long rolling.

Resumo

Durante os últimos anos, o transporte ferroviário de alta velocidade tem se tornado interessate em comparação ao transporte aéreo, para os trajetos breves e de média distância, em termos de praticidade e convenciência de custo. As estimativas indicam que este interesse, iniciado na Europa e no Oriente, encontrará favor também em outras áreas do mundo. Todos os componentes utilizados pelo transporte ferroviário de alta velocidade apresentam requisitos muito rigorosos de qualidade, fato que em particular influencia o processo de fabricação de trilhos. Ao mesmo tempo, a necessidade de aumentar a capacidade dos trens de cargas também requer o melhoramento das caraterísticas dos trilhos. Também para este produto, as forças de globalização direcionam as siderúrgicas para conceitos modernos de produção, onde crescente atenção vem sendo dedicada à flexibilidade, qualidade e rentabilidade operacional. O trabalho apresenta as soluções Siemens para a laminação de trilhos, em particular para os trilhos longos (p. ex. 100 m de comprimento) que oferecem vantagens de mercado e de custo, mas que podem acarretar problemas de *layout* em caso de instalações existentes.

Palavras-chave: Trilhos; Laminação de longos.

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1 GENERAL

In recent years, modernly developed high-speed rail transportation has been gaining a renewed interest for its convenience and cost-effectiveness, which make it a viable alternative over air transportation for short and mid-distances. Forecasts indicate that while this trend started in Europe and Far East, it will likely be followed by other regions of the world as well.
Over the two last decades, railroad networks built or revamped in several countries in and outside Europe, prove that high-speed trains on short or mid-distances may offer a comfortable, safe and convenient alternative to air.
Cruise speeds exceeding 350 km/h call for strict quality requirements, which affect both the manufacturing and maintenance procedures of all components, including in particular the manufacture of rails, for which the resistance to wear and to rolling contact fatigue are of outstanding importance. As vibration and dynamic loads must be maintained within acceptable limits, for safety and comfort, the rail linear tolerances are significantly more tight than with conventional rails. Moreover, as the welding joints constitute a potential origin of defects, the market tendency is toward longer rails (up to and over 100 m). With freight trains, the need for trasporting heavier payloads is also posing the requisite of rails with excellent characteristics.

2 OVERALL LAYOUT

While several layouts have been adopted over the last decades, the modern production requirements call for rolling flexibility and process smoothness, in order to maintain a high efficiency and allow the quick change of production schedule, while minimizing downtimes. An important decision factor is whether the mill is to be designed exclusively for rail production, or the market dynamics recommend the possibility to alter the original product mix, so to include also medium or large sections to be rolled in the same mill.
In case of sole rail production, the best layout to fit these requirements (Figure 1) is composed by two reversing breakdown stands, a continuous universal rolling/finishing train, followed by the optional in-line heat treatment facility, the cooling bed with pre-cambering system (if required), straightening area, and ancillary systems such as sawing units, rail marking, stacking and binding, vision systems. With this configuration rails up to 120 m may be continuously rolled.

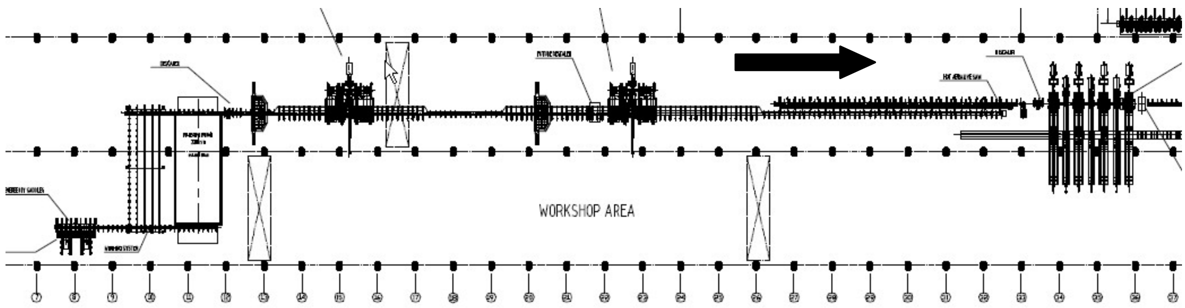

Figure 1. Layout with breakdown mill and continuous univeral mill.

3 BREAKDOWN STANDS

After the casted blooms have been heated in the furnace to the suitable rolling temperature, they are descaled with high-pressure water and then rough-rolled in the

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breakdown mill composed by two 2-Hi reversible stands (Figure 2). An adequate number of reducing passes is critical in order to make the internal structure homogenous. The resulting shape is the leading pass section which varies according to the final rail section. Siemens VAI portfolio comprises the latest generation of breakdown stands with roll diameters 600 mm to 1.400 mm, completed by automatic side guard manipulators. In case of rail mills, the typical roll size is 800 mm to 900 mm, with a barrel lenght of around 2,000 mm. In case of two breakdown stands, they are identical, so to minimize the spare components and optimize the maintenance procedures. Rolls are balanced with hydraulic cylinder, while an electric motor adjusts the gap and compensates the roll bending through a linear transducing system coupled with load cells. The roll neck area offers excellent load capability, the radial force being supported by 4-row taper roller bearing, and the axial load being supported by 2-row thrust taper roller bearing. A roll quick change device allows for rolls to be quickly removed and replaced, keeping the roll change operation within the same rolling bay.

Figure 2. Breakdown stand.

4 CONTINUOUS UNIVERSAL MILL

The universal mill completes the rail rolling, by reducing the leading pass to the final rail shape through a sequence of several continuous steps (Figure 3). It is composed by 5 to 7 universal/horizontal stands, based on the renowned Red Ring design (Figure 4), which allows a fast and easy conversion among universal and horizontal configuration. The same configuration may be adopted when sections up to 300 mm are included in the product mix.

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Among the advantages of rolling rails with a continuous universal mill there are:

- perfect rail shape control (one edging pass after each universal pass);
- high reliability of rolling process (off-line stands pre-setting);
- less heat losses of rail with less power consumption and better tolerances;
- better control on roll wear / longer rolls life / less roll changes;
- smooth rolling process with less equipment maintenance;
- no need to change stand / line set up after each pass;
- reduced down-times for stand changes (quick change device);
- high production rates.

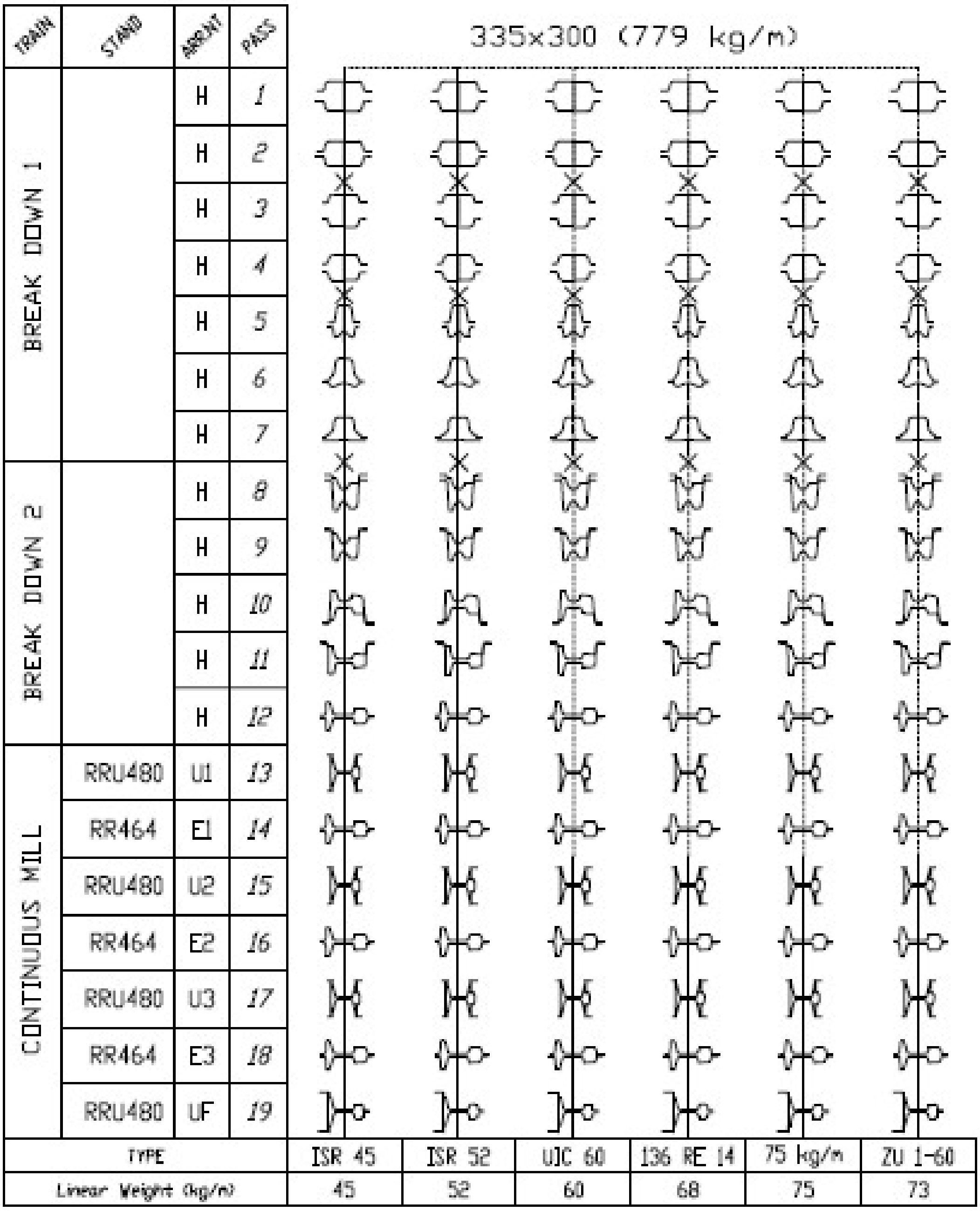

Figure 3. Rail pass schedule in a continuous universal mill.

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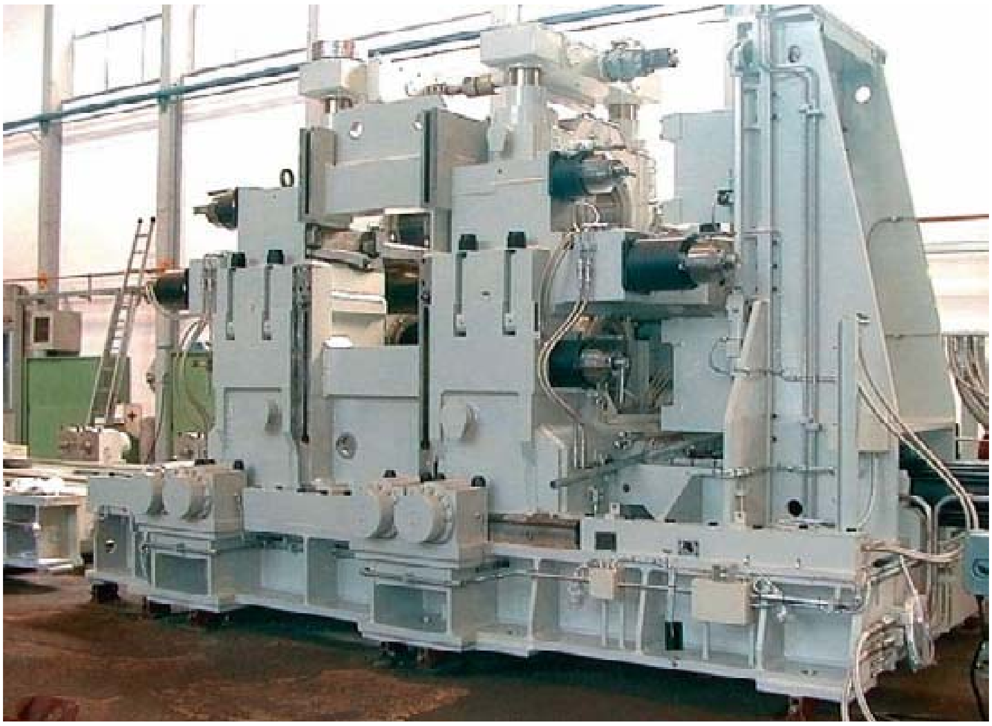

Figure 4. Universal stand on baseplate with spindle holder.

5 UNIVERSAL MILL FOR RAILS AND LARGE SECTIONS

When sections exceed the 300 mm dimension then the proprietary solution 3+1 is adopted (Figure 5). This solutions consists in one reversible intermediate-finishing train with U-H-U configuration, closely followed by a single pass universal finishing stand. The finishing stand is kept open during the reversible operation, and used only for the final rolling pass (Figure 6). Its rolling grooves are therefore subject to a reduced wear, which permits to limit the number of roll changes required to maintain the product quality, and correspondingly to increase the production capacity. Another significant advantage is the compact layout, as the four stands are closely located, with the consequent savings of land, building, ancillary equipment.
Also, the four stands may be serviced by a single stand change system, further reducing downtimes, leading to a more compact rollshop and more efficient crane usage. Spare components are optimized with a better overall inventory management. All the stands are based on the Red Ring design,

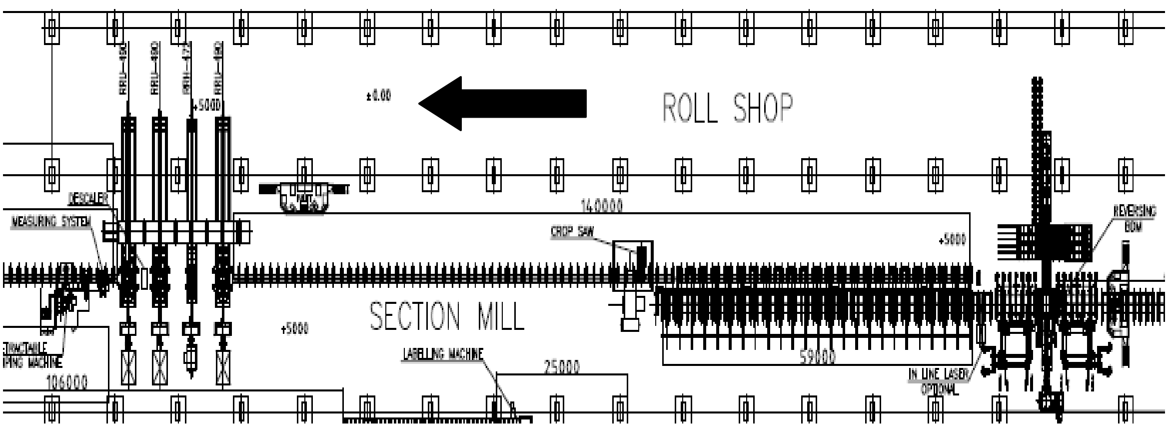

Figure 5. Layout with breakdown mill and 3+1 universal mill.

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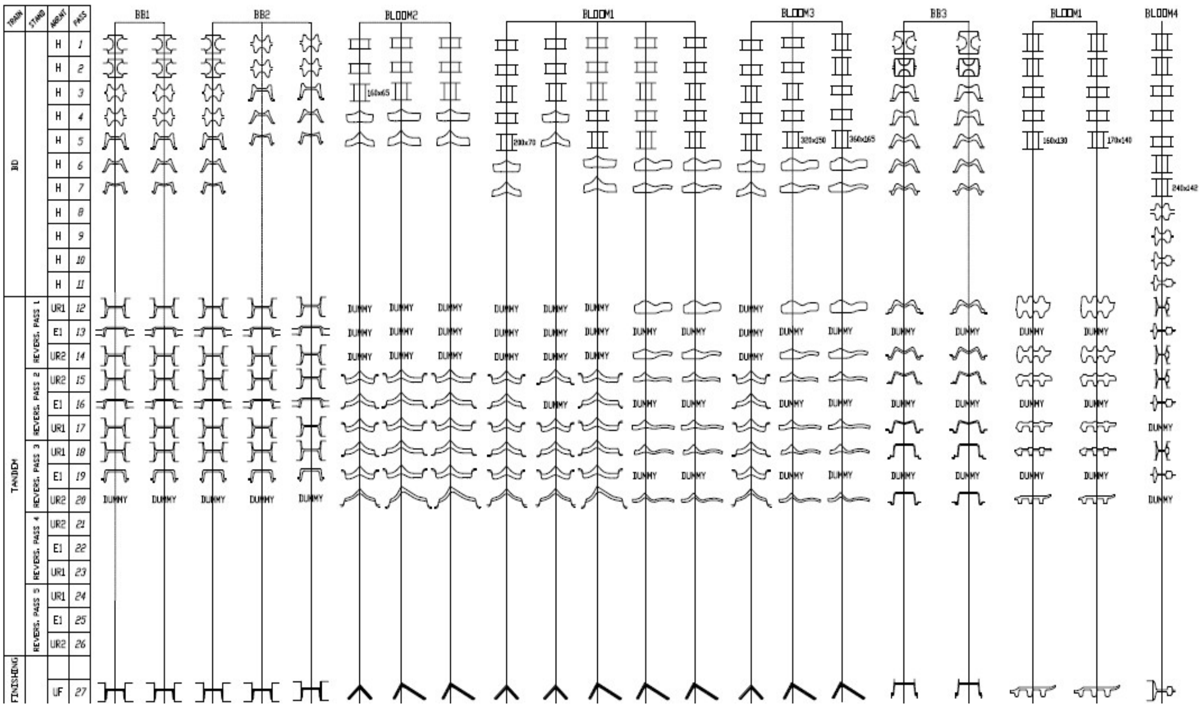

Figure 6. Section and rail pass schedule in the 3+1 universal mill.

6 ADVANTAGES OF SIEMENS UNIVERSAL STANDS

- Fast roll changes: when rolling structural shapes in the mill, universal stands can be exchanged with horizontal stands. in addition to the horizontal rolls, they are fitted with a set of non-driven vertical rolls to work the flange shapes. a special design means that rolls can be changed in just a quarter of the time it used to take;
- easy installation: installing universal stands into existing rolling trains requires no significant foundation work, modifications or lengthy downtimes. so for a minimum investment, a wide variety of mills can be quickly and flexibly upgraded;
- low weight: weighing only half the mass of conventional stands, universal stands allow the rolls and rolling equipment to be quickly and easily replaced. there's no need for high-capacity overhead cranes or costly and bulky extraction carriages;
- remote-control change: a remote-controlled roll change robot helps to significantly reduce the roll assemblies' changeover time.

7 IN-LINE HEAT-TREATMENT PROCESS (HEAD-HARDENING)

Traditionally, standard rails grades are rolled without in-line temperature control, and in order to reach a desired pearlite microstructure, alloy constituents are added during the steel making phase, e.g. Niobium. By deploying some cooling zones along the rolling train, the rolling temperature may be lowered down to approx. 800°C to 850°C, which permits to improve the pearlite matrix while at the same time reducing the high operation costs associated with alloy steel making. Standard rail grades show a limited resistance to wear and tear, due to the contact fatigue generated by the large dynamic loads occurring with heavy payload and/or high speeds. For fixing the inevitable damages to the rails, it would be therefore be necessary to foresee

frequent stoppages for rail maintenance work (e.g. rail re-grinding for crack removal), as well as frequent track replacement. Beside being time consuming, this would also lead to high operation costs.
Nowadays, in order to reach the high capabilities requested by either heavier payloads and/or high speeds, there is a trend towards bainitic structures, which offer improvements of strength, fatigue resistance over pearlite. To obtain them, rail temperature is controlled during rolling, and rails are processed through the in-line head-hardening system, is an advanced heat treatment occuring before the rail is delivered to the cooling bed. The application of dedicated modeling tools permits to precisely control the process parameters of cooling, with finely calibrated actions applied along the rail outer profile, in order to obtained the desired microstructure distribution across the rail section, and with the required hardness values.

8 HOT MARKING

In-line hot stamping machines with rotating heads emboss the web of rails at periodic intervals, with programmable information such as mill ID, name of rail, bar and heat number (Figure 7). This ensures that each individual rolled rail may be easily tracked and identified, for storage, shipping, installation, customer claim purposes, as required by international or country-specific standards.

Figure 7. Hot marking unit.

9 COOLING AND PRE-CAMBERING SYSTEM

Rolled rails enter the cooling bed with a sideways orientation, therefore with a non-uniform mass distribution across the vertical plane of symmetry. Consequently, when cooling on the bed, rails have the tendency to bend inwards on their head side. For standard rail grades, where in-line heat treatments are not applied, If not compensated, this tendency would make post-cooling straightening very difficult. Rails therefore are pre-cambered before being deposited onto the cooling bed and

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are hydraulically clamped and lifted on the web side. The clamps are mounted on motor-driven cars, each with individually programmable travel distances that allow for the application of different pre-camber patterns (Figure 8). Pre-camber geometries are calculated according to cooling models and rail parameters, which include grade, shape, specific mass, length, and temperature. Pre-cambering allows for the rails to be sufficiently straight when entering to the straigheteners, so that the required straightening pressures may be reduced, as well as internal residual stresses. In case of rails processed through the in-line treatment system, pre-cambering is not necessary, as the temperature of the rail entering the cooling bed is low enough for the bending tendency to be disregarded.

Figure 8. Rail pre-cambering.

10 STRAIGHTENING SYSTEM

High-speed train call for extremely tolerances of linearity and shape of rails. This is obtained with a straightening line, where the roller diameter and distance ensure that rails are pressed straight and even, with very low levels of internal residual stress. Before entering the straightening area, a hydraulically operated manipulator positions the rail onto its foot so that its symmetry plane (which contains the rail web) lays vertically. The same manipulator provides a firm introduction of the rail. The straightening line is composed by a horizontal roller and a vertical roller machines, which apply a mechanical pressure sufficient to reach the yield tensile strength, respectively in the web plane and across it.
Straighteners are composed of a rigid frame containing two staggered rows of double-supported or cantilever mounted rollers. The rollers of one row are driven by an electrical motor, while the others are idle. Rollers‘ position and centerline is adjustable according to the rail size and its plastic section modulus. Hydraulic

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counterbalance to eliminate backlashes . The rollers are mounted in a removable cassette. For a quick changing operation, the cassette is automatically removed and replaced with another cassette that's ready with standby rollers (Figure 9). A suction system removes the scale peeling off the rails during straightening, for further filtering and processing.

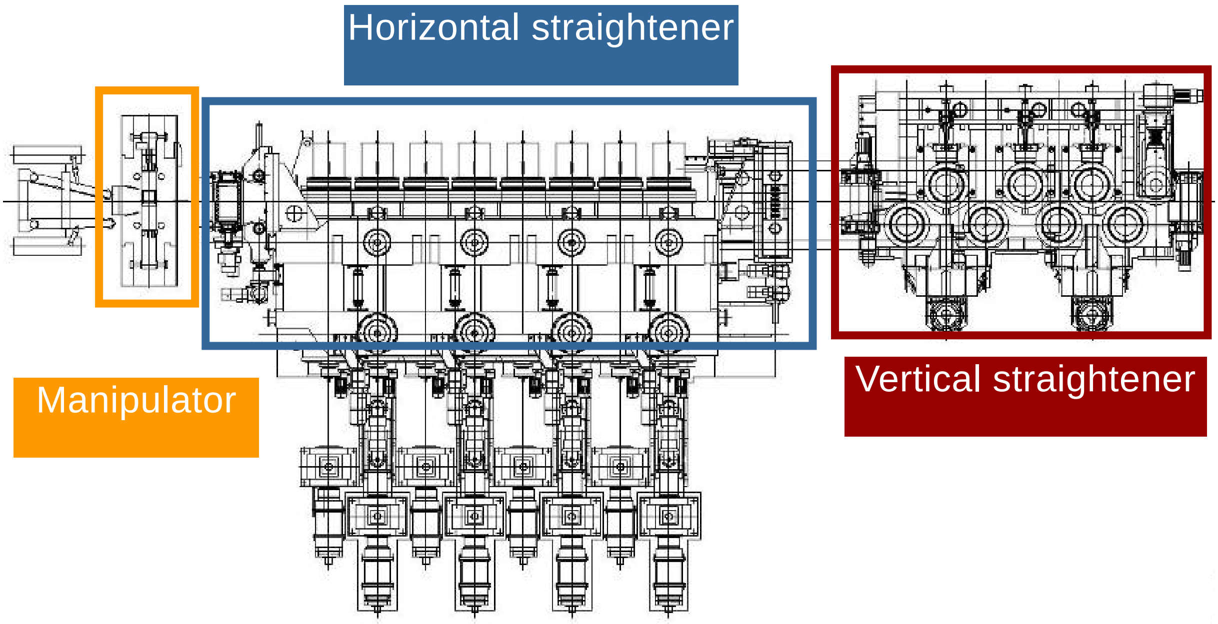

Figure 9. Rail straightening area with manipulator.

12 SAWING UNITS

For hot-cutting rails to its final lengths, sawing may be preferred over shearing equipment (Figure 10). Sawing can eliminate the deformation of rail ends and obtain better cut quality and precision. Depending on the application, process parameters, and operational requirements, hot-sawing processes with either metallic or abrasive disc technologies can be used. This permits to eliminate or significantly relieve the requirements of post-processing operations such as burr removal and edge trimming. During cutting, the rail is firmly clamped at both sides of the wheel. Depending on the dimension and shape of the rails to be cut, the wheel approaching and receding movements can be either pendulum or linear type. Saws are also used for nose and tail cropping, with an automatic crop discharge system. Rail bar samples can also be cut with a special conveyor to separate them. Cut swarf is collected in a bin at the saw, while a separate dust removal and filtering system is provided. An automatic system compensates for the wheel wear and helps to minimize the process cycle time.

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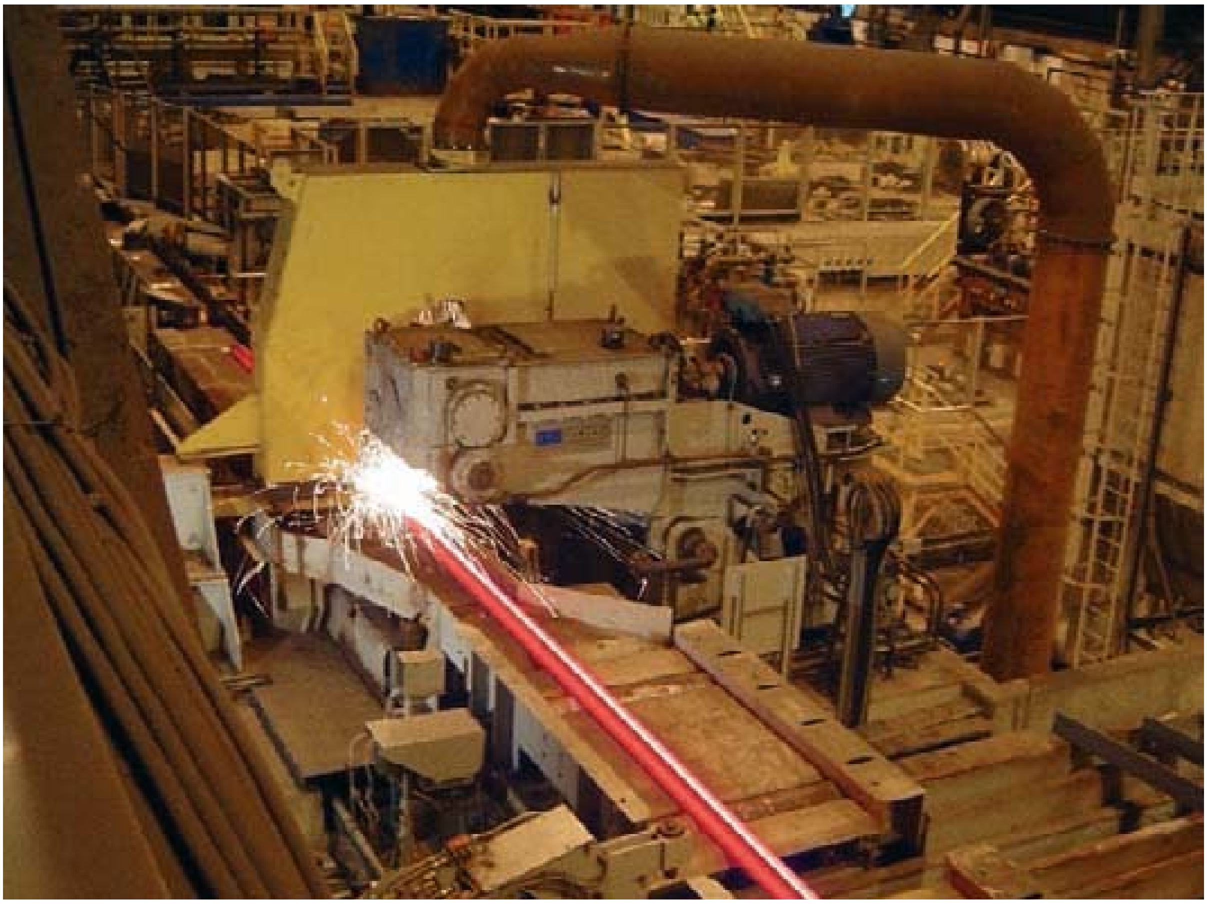

Figure 10. Abrasive disc saw for rails.

13 RAIL MONITORING AND TESTING

Necessary features of high-speed railways are safety, operation reliability, long lifetime, comfort, capacity of large dynamic loads. These requirements call for tight dimensional tolerance and perfect surface finishing during the rail manufacturing process.
The continuous monitoring of rail profile, temperature, rolling speed, rail ID is done at intervals on each rail before it enters the cooling bed with dedicated hardware/software which use special cameras and laser sources. The measured data are feedbacks for the automatic adjustment of rolling parameters, as temperatures, rolling gaps, motor torques. The system can be trained to automatically spot surface defects, and data and images for each rail are stored in a database for documentation purpose.
The non-destructive testing area is located after the straightening units, it serves to ensure that each rail complies with the international and country-specific standards of quality. It comprises an Eddy-current testing unit (Figure 11) and an ultra-sonic device, which check the rail outer surface and internal structure respectively. Linearity tolerances are particularly demanding for high-speed rails (up to 1/10.000 on the whole rail), and are controlled with high-resolution cameras and laser sources.

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Figure 11. Eddy-current testing unit.

14 CONCLUSION

Similarly to what happens in other metal sectors, the globalization trends are forcing the steel industries towards modern production concepts. Flexibility, quality and operational profitability must therefore focuses with great attention.
Like for any other steel product, but particularly for rails, the issue of final product quality cannot be limited to the rolling process, but should rather be addressed in a holistic way, so to include the steel manufacturing (whether via scrap-based electrical steelmaking or via ironmaking route), the secondary metallurgy and the bloom casting methodology.