The rolling mill for rails and structural sections at ARBZ*

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Abstract

The market for new railways, and its associated components, is on the increase. Rail transport for passengers and freight is assuming a role of growing importance. Cost-effectiveness and reduction of polluting emissions are among the main reasons for this. In fact, all technical standards have been reviewed in order to comply with the new demanding requirements. In Kazakhstan, the first rail manufacture is operating in the town of Aktobe, with the new ARBZ state-of-the-art mill for rails and sections.This paper outlines the scenario of rail market, and describes the ARBZ installation, with its most significant technical and process aspects.

Keywords: Rail, Universal rolling, Rail hardening, Contact fatigue

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1. Introduction

The ARBZ rolling mill for rails and sections in the town of Aktobe is the first rail manufacture in Kazakhstan. Considered among the world benchmark manufactures of rails, it caters to the growing demand from the domestic market and the neighboring countries.The rails are pre-certified per GOST standard and, besides saturating the domestic market, are exported to the Russian Federation and CIS countries. The mill is capable to roll standard and premium rails with length up to 120 m, with improved mechanical features and high resistance to contact fatigue and wear.Medium structural sections such as beams, channels and angles can also be rolled.

2. The market for rails and its requirements[1] [2] [3] [4]

The role of rail transport of both passengers and freight in the world has a growing importance, despite some disparities among the geographical areas.The global rail market reached a 3% CAGR in 2013-2015, and is forecast to continue at sustained values of growth until 2021, when the market is expected to reach 185 bn EUR. In addition to their cost-effectiveness, railways can significantly contribute to the reduction of CO_2 emissions, especially when powered by non-fossil electricity.

High-speed passenger systems improve transport within large urbanized areas, and can strongly compete against air travel over short- and mid-distances, both on cost and door-to-door time convenience.Freight transport with long train compositions and high loads-per-axle improve the cost-effectiveness of transportation of bulk materials, such as ores and crops.

High-speed needs rails with the longest possible length, in order to minimize the rail joints and favor comfort and safety of transport. Besides, curved portions of the rail tracks must resist to the large centrifugal forces.High-load requires that the railsbe resistant to rolling contact fatigue and wear, in order to lessen the costly maintenance operation.To incorporate these requirements, all the major national material standards were updated during 2010-2015.

To meet the high-speed and high-load demands, rail manufacturers must take the product quality to higher levels than those considered sufficient only at the end of the twentieth century.Rail manufacturing units are expected to efficiently produce rails in a wide range of grades, sizes and lengths, with mechatronically-assisted setup procedures and self-adapting operations governed by process control. These are the tenets of Industry 4.0 which enliven the digitalized manufacture, with considerable benefits to product quality, shortening of start-up times, reduction of running costs, operation flexibility and preservation of resources.

3. Rail manufacture in Kazakhstan and ARBZ

Since the early 2010s the multi-year framework of the Industrialization Map of Kazakhstan has considered the development of railway infrastructure among the most important priorities to foster the industrial and commercial growth of the country.Similar calls existed in neighboring CIS countries.

Underthe auspices of Kazakhstan Temir Zholy JSC, the national railway company, in 2012 the later called ARBZ venture was established, and the decision taken to build the first rail manufacturing plant outside the city of Aktobe in the north-west part of the country, some 100 km from the border with the Russian Federation.Aktobe is strategically located right at the center of Asia, in a barycentric position among Europe, Russia, CIS and Middle East.Besides rails, the plant was to be capable to manufacture also medium-size structural sections, such as beams, channels and angles.This would allow the industrial operation to maintain enough flexibility to quickly adapt to possibly changing scenarios of the market.

4. Layout and rollable products

The ARBZ rail and section mill in Aktobe has a nominal production capacity of 430,000 tons per year.The overall plant footprint is approximately 650 x 150 m, remarkably compact for a facility designed to process rails with length up to 120 m (figure 01).

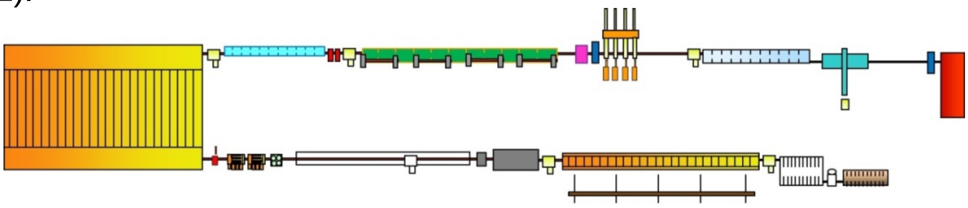

Figure 01. Sketchy layout of ARBZ mill

Besides some200,000 tons per year of rails P65 65 kg/m in lengths of up to 120 meters, the product mix comprises 230,000tons per year of structural medium sections, including beams and channels up to 300 mm, and angles up to 200 mm.As starting material, square blooms with size between 160 and 350 mm are used, with length from 5 to 12 m.The configuration of layout and equipment allow the expansion of the product mix to additional rollable sizes, and the possibility to use beam blanks as starting material.After being re-heated in the furnace, the bloom is rolled in a reversing breakdown mill and transferred to a tandem mill for finish rolling.Depending on requirements, railsmay be head-hardened by an inline controlled system, before being deposited on the cooling bed.Cold rails and sections are straightened and then subjected to non-destructive tests before final handling and dispatch.Other included packages are the descaling systems, inline profile measurement, rail stamping unit, hot and cold saws for cutting and web drilling, laboratories and a maintenance workshop.

5. Key equipment

5.1. Bloom re-heating furnace

The walking-beam type furnace (figure 02) has a rated production capacity of 90 tph of blooms with 300 x 360 mm sides and 9,700 mm length. Burning natural gas with 8,500 kcal/Nm^3, the furnace heatsthe blooms at the maximum temperature of 1,250°C. The furnace features independent heating zone, with roof and bottom burners, to provide the efficient transfer of thermal energy. The rated specific consumption is 295,000 kcal/t.A high-pressure descaler working with water at 250 bar is provided at the furnace exit side.

Figure 02. Bloom re-heating furnace

5.2. Reversing breakdown mill and calibration design[5]

The breakdown mill is a 2-high, reversing, housing-type machine with a roll barrel length of 2,200 mm (figure 03). The nominal roll diameter is 940 mm and the maximum working roll centerline is 1,500 mm. The housing design provides the stiffness required to withstand the high separating forces with minimum deformations. The breakdown mill is driven by one 4,000 kW AC motor.

Figure 03. Reversing breakdown mill

The machine is equipped with automated lineals and tilters located at both entry and exit, which serve to rotate and translate the bar in between the rolling passes and guide it into the selected groove.Separate bar turner are used when sections are rolled.The rest bars used for section rolling are fitted on roll chocks, for easy setting in the rollshop and quick change operation. For rails instead, the conventional guiding system is replaced by simple shoe plates.The top roll is hydraulically balanced, and its vertical positioning is provided by a screw-down system, driven by two independent servo-controlled motors which automatically compensate possible asymmetries. The screw-down system is in compound material, with alloyed steel and nitriding/anti-friction coatings (Nipre®- Nitox®) for increased wear resistance and extended lifetime.Chocks are securely clamped on the housing by means of hydraulically operated latches, while breast and bar feeding rollers assist the mill at both entry and exit sides. At the machine bottom, hydraulic capsules are installed at the bottom to:

- adjust the centerline position of the bottom roll
- provide anti-jamming release function
- automatically position the bottom roll when change sequence is launched
- automatic control of rolling force

The stand change sequence is fully automated, and the total downtime is limited to approximately 30 minutes. A hydraulic cylinder pulls the assembly of chocks/rolls out of the housing and positions it onto a roll change track, where a new assembly is ready to be pushed back inline. During change, the disengaged spindles rest on hydraulically driven sleeves.Separately and offline, the disassembly and assembly of rolls and chocks are realized on dedicated automated jigs in the workshop, where roll turning and other maintenance are also performed.

An innovative rolling design for rails is employed at the breakdown mill, with the symmetrical open-pass calibration which allows to obtain a stable dimension of stock on the whole bar length, and reduces the risk of fin and wrinkle formation. At the same time, the guiding system is simplified and axial loads reduced.The closed-pass calibration traditionally used for rails requires complex rolling sequences and bulky guide equipment with side collars which limit the usable barrel length. With symmetrical open-pass calibration instead, the rolling sequences are simplified and the bar is simply and effectively guided by the lineal noses and shoe plates.Avoiding complex guiding systems with collars, the full roll barrel length can be utilized and rolls with smaller barrel and diameter can be used.The uniform groove wear is promoted, the roll working life is increased and reworking times are reduced, which contributes to the reduction of transformation costs. All in all, the mill management is simplified.When manufacturing the P65 rail from a 360x 300 mm bloom, nine passes are rolled at the breakdown mill to prepare the leader pass. The first six passes are high-reduction box-type and guarantee the metallurgical properties as grain size and core soundness; the final three passes are shape-type and provide the precise leader pass required to feed the finishing mill. The combination of a single breakdown mill with open-pass calibration and a finishing mill with four stands allows to apportion the total reduction work in the ratio of 40% and 60% respectively. This is consistent with the related investment cost for equipment.

5.3. 3+1 universal finishing tandem mill

After the breakdown mill, the bar is cross-transferred so to disengage the rolling between roughing and finishing and limit the plant footprint. The bar head is cropped by a cutting saw and the secondary scale removed by a high-pressure hydraulic descaler.The universal finishing tandem mill is composed by four housingless-type stands closely arranged. The stands have the following configuration:

1. RRU-480, driven by a 3,000 kW AC motor, for universal rolling
2. RRH-472, driven by a 1,500 kW AC motor, for horizontal rolling/edging
3. RRU-480, driven by a 3,000 kW AC motor, for universal rolling
4. RRU-480, driven by a 1,500 kW AC motor, for universal finishing

All the stands are the fourth generation of the RedRing family. The RedRing design offers a solid and compact construction for a high load capacity, is wear-resistant and maintenance-friendly (figure 04).

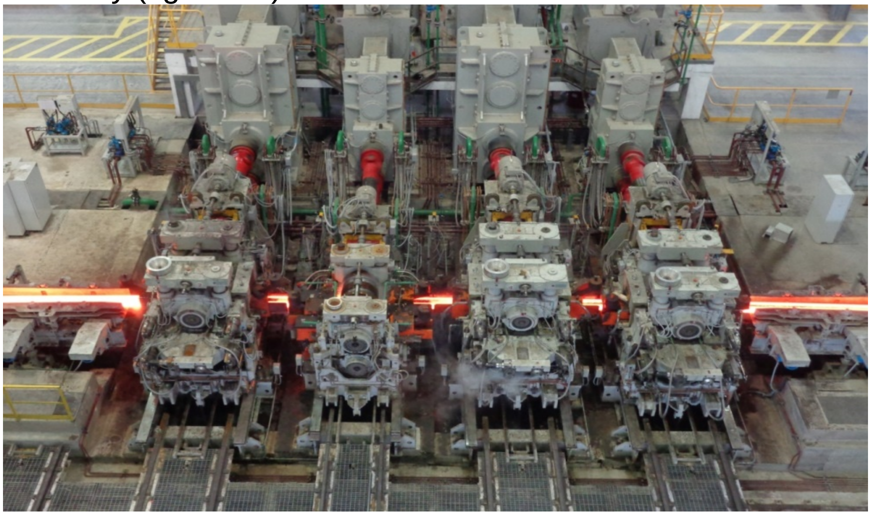

Figure 04. 3+1 universal finishing tandem mill

The stands can be individually or jointly changed with the assistance of the automated change device. With the use of spare units prepared in the rollshop the total downtime is shorter than 30 minutes. Offline in the workshop, the stand parts (horizontal rolls, vertical rolls, chocks, baseplate) are disassembled and assembled with dedicated automated jigs.The three RRU-480s can be quickly converted from universal to horizontal configuration and viceversa. They have a roll barrel length of 750 mm and a maximum working centerline distance of 1,040/820 mm. The RRH-472 has a roll barrel length of 750 mm and a maximum working centerline distance of 690 mm.The universal configuration is used when rolling rails, beams and channels, while a full horizontal configuration is used when rolling angles. The leader pass prepared by the symmetrical calibration of the breakdown mill is processed with a reversing three-run sequence.

With the 3+1 finishing mill a sequence comprising three reversing runs is used. The reversing runs allow a good control of the bar temperature and of its head-to-tail gradient, which contributes to the reduction of loads and of size variations.The peculiarity of the 3+1 concept is that, during the first two reversing runs, the fourth finishing stand stays open and is not used. It is only closed during the third run, thus it is used only once on each bar. The reduction applied by the finishing pass is small (kind of a sizing pass). Consequently, rolling and thermal stresses are low and the induced roll wear is limited. This allows a longer useful life of the rolls, fewer requirements of roll changes, shorter downtimes, higher productivity.

In fact, in a traditional three-stand finishing mill,all the standsare used during run-rolling, hence the rolls in the final stand wear out fairly quickly due to rolling and thermal stresses. Therefore, to guarantee the required surface quality of the finished product, redressing or roll change operations are typically required every some 1,000 tons at most.Conversely, the rolls in the fourth stand of the 3+1 mill are subjected to lower stresses, and they only need to be serviced every 2,000-3,000 tons. Now, usually rolling campaigns for rails and sections are in the range of 2,000-2,500 tons, which means that in a 3+1 mill changes become largely unnecessary, and one roll setcan be used for the whole campaign. Shorter downtimes mean a higher number of available hours and an increase of productivity. The additional investment for the fourth stand is quickly repaid, while the total number of required rolls does not change significantly.Another advantage of the dedicated finishing pass with small reduction is that quality results of both surface smoothness and size accuracy are guaranteed. This is especially appreciated when special class products are rolled, for example X-class rails whose size tolerance field is about half of the conventional Y class.

After exiting the 3+1 mill, the finished profile is measured by a ProScan optical system, while a stamping machine provides the required markings on the product.

5.4. Inline hardening system idRHa+[6]

In order to produce rails with a high resistance to rolling contact fatigue and wear, the mill at ARBZ is equipped with an inline Injector Dual-phase Rail Hardening (idRHa+) system, developed in partnership with Centro Sviluppo Materiali RINA-CSM.The idRHa+ system is based on a suite of process simulation models for thermal transfer, mechanical properties and metallurgy. The suite integrates with the equipment advanced sensors and mechatronics, thus implementing Industry 4.0 production management solutions. The models are validated by field tests and provide the prediction and real-time control of the rail properties along the length and across the section, such as YTS, UTS, hardness gradient, microstructure transformation and deformation behavior. The cooling protocols provided by the models are applied by the equipment modules, which are located inline with the finishing rolling operation, so that productivity is not affected. The real-time measured values are used to dynamically adjust the process and the equipment. As a result, the desired microstructure and hardness distribution across the rail section are obtained with high precision.

Before entering the idRHa+, rails are cropped by a metallic saw, turned to a head-up position and pre-straightened.A first heating zone is equipped with a system comprising a set of high-power induction modules, which can efficiently transfer heat to the rail in short times and spaces. The heating action equalizes the temperature of the rail along its length, and applies the desired temperature gradient over its cross section.

The cooling zone contains several independent modules, each equipped with a set of interchangeable cooling devices which apply the required cooling protocols. Mist-water atomizers and air-jet blades are used. Models are independently operated, so to have a good flexibility of cooling protocol application (figure 05).

Figure 05. Inline hardening system idRHa+

Depending on the processed grade, the cooling speed is adjustable in the range of 0.5÷40°C/s in accordance with the required microstructure and mechanical characteristics. Rails which are head-hardened by idRHa+ are sent to the cooling bed in the head-up position. Due to the quenching effect, they are not prone to bulging and do not need to be pre-cambered.

5.5. Cooling bed

The mill is equipped with a125 mwalking-typecooling bed, capable to handle rails with 120 m maximum length. At the bed entrance, a metallic disc sawing machine is provided for bar cut-off and product sampling.The cooling bed consists of a series of stationary and walkingbeams, with hydraulic cylinders and valves providing synchronized lifting and travel movements. The cooling effect is by natural air flow (figure 06).

On the cooling bed, non-hardened rails rest on their side. They tend to bulge inward on their head side, due to differential cooling gradients in the section, with alternating elongating and shrinking effects until the room temperature is reached. The resulting distortion and internal stresses at the cooling bed exit would be too high, especially for longer rails, which could not be effectively processed by the straightening equipment.To offset this effect, a pre-cambering system is installed at the cooling bed inlet table and applies a controlled outward bulge on the rail.Every 3 m approximately, the rail is secured on its web by a set of shaped grippers which are hydraulically operated. The grippers are mounted on cars which can independently travel up to 5 m and apply the desired camber to the rail. Cars are driven by gear-motors. During travel, the rail is maintained lifted so to avoid any damage by friction. According to the rail size and type, a simulation model calculates the travel length of each car and defines the pre-camber patterns, which are stored as recipes in the control system. Conversely, rails which have been hardened by idRHa+do not show the bulging tendency, and rest on the cooling bed in the head-up position.

Figure 06. Cooling bed with pre-cambering

5.6. Straightening systems

The combined effects of the mechanical work from rollingand of inhomogeneous cooling produceconsiderable values of internal stresses retained by the product at the cooling bed exit. International standards prescribe acceptable limits of the internal stresses, in order to prevent the distortions of the final product. Inline roller straightening is the last process of plastic deformation along the chain of production. The straightening process consists in the application of calculated and controlled plastic deformations along the bar length. During straightening the internal stresses are released and brought down within acceptable values, while precise straightness tolerances are obtained.

5.6.1. Horizontal straightener for structural sections

A horizontal multi-strand straightener is installed at the cooling bed exit, to process structural sections (beams, channels and angles). The machine has9 double-supported staggered rollers, pitched at 650 mm between centers.The 5 upper rollers are drivenby a single motor via a gearbox, while the 4 lower rollers are idle. The maximum diameter of rollers is 560 mm and the barrel length 500 mm.The lower rollers are provided with axial adjustment. The vertical position of the upper rollers is adjusted electro-mechanically according to the product size, while hydraulic cylinders compensate the backlashes (figure 07).

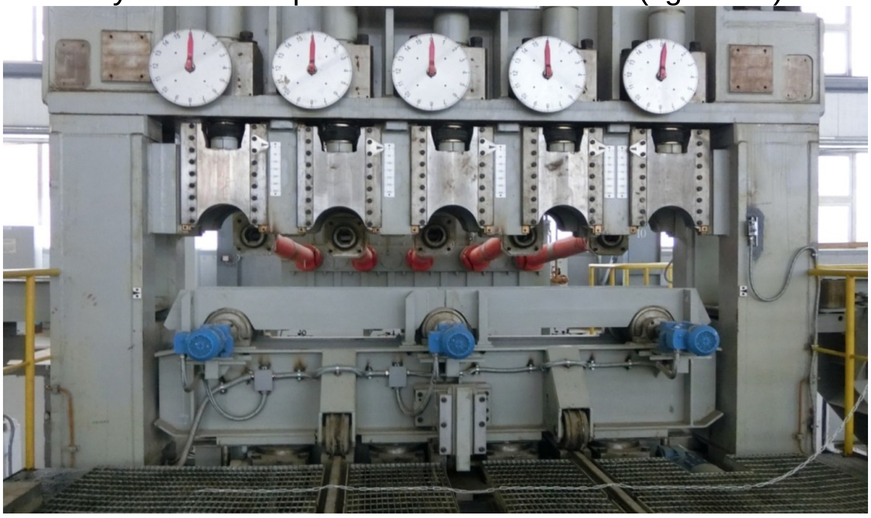

Figure 07. Horizontal straightener for structural sections

Straightening recipes are available in the control system for the quick setting of the machine parameters.

5.6.2. Horizontal straightener for rails

A machine with horizontal rollers is used to straighten rails in the horizontal plane, by applying a controlled plastic deformation on the rail head and foot. It is equipped with 9double-supported staggered rollers, pitched at 1,600 mm between centers.All the four upper and five lower rollers are independently driven, and the machine can operate at a maximum speed of 2 m/s. The maximum diameter of rollers is 1,000 mm and the barrel length 500 mm. Before entering the machine, non-hardened rails are turned to a head-up position.The straightener is composed by two side frames which support the shafts and the roller chocks. The shafts are equipped with hydraulic locks, which quickly engage and disengage during the automatic change operation of rollers. The automation relies on a full mechatronic control. Sensors, transducers and actuators communicate with the control system during the straightening process, and guarantee the quality of the operation, its repeatability and consistency along the entire rail length. The electronics are mostly contained in a separate external enclosure, for protection and easy accessibility. Each of the nine rollers is individually driven by a motor and gearbox (figure 08).

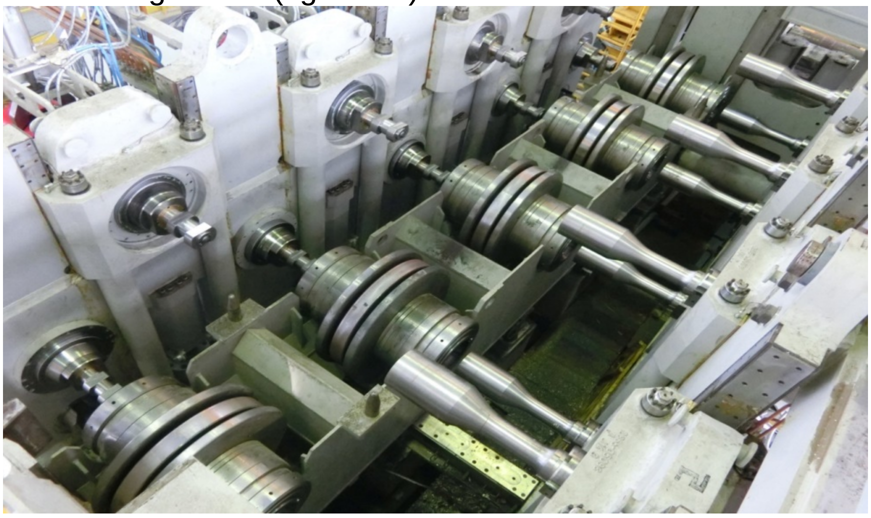

Figure 08. Horizontal straightener for rails

Independent axial adjustment is provided on both upper and lower rollers.
The vertical position of each of the upper rollers is adjusted via hydraulic capsules, which also compensate any backlash. The hydraulic capsules connect to the chocks of the upper rollers, and are equipped with digital pressure and position transducers. The pressure/load and position of each shaft are recorded and input to the mechatronic control. As load vs deformation curves are known for each of roller, the roller position can be automatically adjusted under load and in real time. This closed loop control guarantees a very precise and effective straightening operation. The calculated straightening recipes stored in the system are automatically fine-tuned during the actual operation. Potentially critical conditions due to excessive loads are avoided by emergency pressure-relief valves.

5.6.3. Vertical straightener for rails

A machine with vertical rollers is used to straighten rails in the vertical median plane, by applying a controlled plastic deformation on the rail web. It is equipped with 8 cantilever staggered rollers, pitched at 1,100 mm between centers.Left and right sides have each 4 cantilever-mounted rollers, which are independently driven, with 750 mm maximum diameter and 450 mm barrel length. The machine can operate at a maximum speed of 2 m/s. Independent axial adjustment is provided on rollers at both sides. The horizontal position of the rollers on the left side is adjusted electro-mechanically according to the selected straightening recipe, while hydraulic cylinders compensate the backlashes. Load cells are provided, in order for the machine to automatically disengage in case excessive loadsare measured (figure 09).

Figure 09. Vertical straightener for rails

6. Certification processes

The national certification according to Kazakh standard could be completed in a very short time, as the project scope included the in-house certification laboratory.ARBZ then entered the multi-year certification process according to the Russian standards GOST, and a pre-certification was obtained in November 2016 after a rigorous six-month testing protocol at the All Russian Railway Research Institute (VNIIZhT).Outside Moscow, Russia, VNIIZhT operates a railway loop where the rails under test are subjected to a variety of operating conditions, such as train composition, load distribution, time, acceleration, speed, braking, gradient, etc.The conditions of the rails are examined during and after the test, so that an exhaustive investigation of all the occurrences of wear and damage may be completed (figure 10).

Figure 10. VNIIZhT's railway testing loop near Moscow (Russia) [7]

7. Project schedule

The ARBZ venture was established in 2012 after the approval of investment, and the main contract awarded to Primetals Technologies in 2013.Engineering, software design and manufacturing took place in 2013-2014, and erection started in 2014. Hot commissioning started in September 2015 and the certification processwas initiated in February 2016. The plant acceptance certificate was signed in August 2017, and in November of the same year the parts entered into a long-term agreement for the spare warehouse management, in order to maximize the plant availability.

8. Conclusion

The 430,000 tpy ARBZ rolling mill for rails and section is the first manufacture of rails in Kazakhstan. It also represents a worldwide benchmark for premium rail manufacturing.The mill can roll both rails with length up to 120 m and structural medium-size sections, such as beams, channels and angles. In industrial operation since 2015, the plant was accepted in 2017. In early 2018, the mill is producing high-strength pearlitic rails P65 DT350 for high-speed applications, with 100% of production being head-hardened with the idRHa+ process. Besides saturating the domestic market, ARBZ rails are exported to Russian Federation and CIS states. Rails have also been manufactured for tests in other European countries and Middle East.

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10. Trademarks

idRHa+ is a registered trademark of Primetals Technologies