Analysis of the main trends in the development of rail production in Russia and abroad

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Abstract. The present analysis reveals the main directions in the development of rail production in the world: the transition to rolling of rail sections using continuous group of universal stands, increase of the rails length, application of differentiated hardening of rails in different media. It is shown that the technological gap between the Russian metallurgical industry and the world’s leading rail manufactures of the last decades was closed in 2013-2014 when the new universal rolling mills at JSC “EVRAZ Consolidated West Siberian Metallurgical Plant” (“EVRAZ ZSMK”) and OJSC “Chelyabinsk Metallurgical Plant” (company “Mechel”) were launched. Currently, these steel enterprises provide complete import substitution of long rails with increased wear resistance for the construction of high-speed networks.

1. Introduction

Nowadays, Russia occupies one of the leading positions in the world as to the length of railways (86000 km). However, it is not sufficient to provide the necessary track capacity, because the share of rail transportation is about 85% of the total volume of cargo transportation. Also the low track capacity of 6000 km of the railway network should be noted due to the high degree of wear. In general, railroad infrastructure wearout reaches 85%.

In order to solve this problem the company “Russian Railways” (“RZhD”) is planning in parallel with the replacement of the worn parts of railway network to construct 22000 kilometers of new railway lines by the year 2030, which conditions the annual demand in rails at the level of 1.6-1.7 million tonnes. At the same time the improvement of the railway infrastructure is possible only alongside with a substantial increase in the quality and durability of rails.

In this regard the urgent task consists in the analysis of the current state of rail production in Russia and its compliance with the level of the world’s leading rails manufacturers.

2. Discussion of the problem

Currently, in the world’s rail production three main trends can be distinguished:
• transition to the rolling of rail sections using universal stands;
• increase in the length of the finished rails;
use of the differentiated hardening technologies.

Rail rolling technology in the universal passes has been actively implemented in the world steel industry since the 70s of the XX century due to the presence of a number of significant advantages over the obsolete scheme of rails rolling in the two-roll passes of stands “duo” and “trio” [1-5]:

- In contrast to the rails rolling in the two-roll pass during deformation in the universal pass the railhead is subjected to direct compression on the rolling surface (Figure 1). Because of that after rolling in the railhead a dense fine grain metal structure is detected, which leads to high mechanical properties and wear resistance of this rail element during operation.
- A decrease in the internal stresses in the rails due to the simultaneous uniform deformation takes place, which greatly reduces the possibility of defects and increases the rail straightness.
- There is a reduction in the slip of the metal relative to the rolls with respect to the vertical (idle) rolls, which reduces their wear and, as a result, the consumption of rolls for a pass goes down. Also the reduction in energy consumption and improvement of the rail quality are achieved.

![Figure 1](image)

**Figure 1.** Deformation scheme of the rail section: a – in the two-roll pass; b – the universal pass (1 – billet; 2 – an intermediate section; 3 – finished section).

For the first time the process of rail rolling in the universal mill stands passed pilot industrial testing in 1964-1968 in France [6]. Further company “Sacilor”, which is the developer of this technology, sold the license for universal process of rails rolling to companies “Nippon Steel” (Japan), “Iskor” (Republic of South Africa), “Whelling-Pittsburg Steel” (USA), “Broken Hill Proprietary” (Australia), “Acominas” (Brazil) [4]. These companies in the 70-80s of the XX century built or reconstructed the operating rolling mills implementing rails rolling in the universal mill stands. Despite some technological and design features of these rolling mills the common rolling scheme consists in the deformation in one or two reversing rolling stand, then the rolled stock is transferred for rolling in the universal reversing mill stand “duo” and to the installed before and after them the auxiliary two-roll mill stands. The final pass is usually carried out in a separately installed finishing universal non-reversing rolling mill stand.

The period of the 90s in the XX century – the beginning of the XXI century is characterized by the intensive dissemination of this technology with the use of universal mill stands. From 2002 to 2009 8 universal rail rolling mills in different regions of the world were put into operation: 3 rolling mills in China, 2 – in India and one rolling mill in Austria, the USA and Saudi Arabia (Table 1).

**Table 1.** Commissioning of rail rolling mills.
The typical pass design of rails of the leading equipment supplier company “SMS Meer” (Germany) includes production of a T section from rectangular billet in the first three passes, then rolling in the rough closed and open two-roll passes (passes No. 4-7) with the subsequent deformation of the obtained section in the universal mill stands of the rail-finishing mill (passes from No. 8 to No. 13) – Figure 2.

Figure 2. Typical pass design of rails for rails rolling developed by SMS.

Increase in the length of the finished rails is one of the trends in the development of rail production. When the technology of continuous rails laying is used, allowing the movement speed to be increased, the increase in the rails length would reduce the number of joint welds. Currently, everywhere on the high-speed networks rails of 100 m long are used, in Japan the production of 150-meter rails was
launched and further it is planned to increase the length of the finished rails. Thus, modern rail rolling mills are intended for production of long-length rails as a main rolled product.

A characteristic feature of the technological process of rails production on the modern rolling mill is the use of differentiated hardening instead of outdated technology of volumetric hardening in oil [7-9]. At present, the technology of differentiated hardening in various media (compressed air, water, polymers) is successfully applied, as for example, during the rolling heat or separate rails heat before the heat treatment (Table 2).

Table 2. Technological features of rails produced by the world’s leading manufacturers.

| Country-producer of rails | Type of a unit for steel smelting | Method of rails heat treatment                                      |
|---------------------------|-----------------------------------|--------------------------------------------------------------------|
| France                    | BOF                               | Two-sided hardening by compressed air from a separate volumetric heat HFC |
| Japan                     | BOF                               | Two-sided hardening by compressed air from rolling heat             |
| USA                       | BOF                               | Two-sided hardening by water from rolling heat                      |
| Canada                    | Electric furnace                  | Two-sided hardening by compressed air from volumetric heat HFC      |
| Austria                   | BOF                               | One-side hardening in the polymer solution from the rolling heat    |

Differentiated hardening makes it possible to obtain higher wear resistance of the railhead while maintaining sufficient ductility of the remaining elements of the rail section. Comparative analysis of mechanical properties of rails obtained with the use of differential hardening and the rails with volumetric hardening shows a lower limit of endurance of the latter (Table 3).

Table 3. Comparative analysis of mechanical properties obtained by various methods of heat treatment.

| Country-producer of rails | Method of heat treatment of rails                                      | Fracture energy, tm at t = -60°C | Endurance limit, MPa |
|---------------------------|------------------------------------------------------------------------|----------------------------------|----------------------|
| Russia                    | Volumetric hardening in oil                                           | >10                              | 400-407              |
| France                    | Two-sided hardening by compressed air from a separate volumetric heat HFC | >10                              | 477                  |
| Japan                     | Two-sided hardening by compressed air from rolling heat               | 5.5                              | 430                  |
| Canada                    | Two-sided hardening by compressed air from volumetric heat HFC        | >10                              | 453                  |
| Austria                   | One-side hardening in the polymer solution from the rolling heat      | 5.5                              | 423                  |

The state of the rail production in the first decade of the XXI century was characterized by a significant technological gap between the Russian enterprises and the leading world’s manufacturers. Production of rails by two steel mills – JSC “EVRAZ Consolidated West Siberian Metallurgical Plant” (“EVRAZ ZSMK”) and “EVRAZ Nizhny Tagil Metallurgical Plant” (“EVRAZ NTMK”) was carried out on the rolling mills of a line type constructed in the 30s of the XX century. 25-meter volumetric hardened rails, produced by the mills, did not comply with the world’s standards on service durability, straightness and a number of other parameters. Besides, for the construction of new high-speed networks such as Moscow-St. Petersburg, long-length (100 m long) rails were needed.
This situation made the company “Russian Railways” buy rails from foreign manufacturers. If the share of rails manufactured by foreign companies (“Voestalpine Schienen GmbH” (Austria), etc.) was 18% of the total purchases in 2011, then by 2012 it went up to 39%.

The radical change in the situation took place in 2013-2014 following the launch of the first in Russia universal rolling mill at “EVRAZ ZSMK” [10].

The composition of the main equipment for the rolling mill, supplied by the company “SMS Meer” (Germany), included (Figure 3): a heating furnace with walking beams; water descaling device for the primary and secondary scale; sequentially located two-roll reversible breakdown stands (BD1 and BD2); universal tandem mill, installed with an offset from the rolling line and consisting of two universal (UR and UF) stands and one horizontal auxiliary stand (E), separately located finishing calibrating universal stand (U0), devices for automatic measurement of the finishing section, automatic stamping machine.

![Figure 3. Arrangement of rolling mill equipment at “EVRAZ ZSMK”: 1 – heating furnace; 2 – water descaling device; 3, 4 – breakdown stands BD1 и BD2; 5 – tandem-group; 6 – hot saws; 7 – finishing stand; 8 – laser measurer of section; 9 – stamper; 10 – area of differentiated hardening; 11 – refrigerator area.](image)

The main rolled products of the universal rail and structural steel mill “EVRAZ ZSMK” are hundred-meter differentially hardened rails. One of the main features of the technological mode of rails production on this mill is the use of differential hardening by the compressed air from the rolling heat. Today, a similar technology of long-length rails hardening is used only in Japan (company “Nippon Steel”) – Table 2.

Lack of experience in the production of rail sections using the universal rolling in the domestic steel industry and the limited amount of information in foreign sources led to significant technological difficulties during the start-up and at the beginning of rail and structural steel mill operation. In particular there was an increased rejection of rails due to the surface defects of rolling origin, low productivity of the rolling mill, increased wear of the mill rolls. The solution of these technical problems was made in parallel with the adjustment of modes of differentiated hardening [11, 12]. As a result, the first commercial batch of long rails produced by “EVRAZ ZSMK” was delivered to the “Russian Railways” in May 2014. That year the company “Russian Railways” completely abandoned the procurement of rails from foreign manufacturers.

Also in 2013 a new universal rail and structural steel mill at Chelyabinsk Metallurgical Plant (company “Mechel”) was officially put into operation. However, the first industrial batch of long rails produced by this plant was purchased by the “Russian Railways” only in 2016. It should be noted that Chelyabinsk Metallurgical Plant had no previous experience in the production of rail products. Supplier of the rolling mill equipment was company “Danieli” (Italy), the construction of the rail and structural steel mill was carried out by “Minmetals Engineering” (China).

Release Organization of a hundred-meter rails production that complies with the world’s standards at the Russian enterprises required significant investments. Costs for the construction of a universal
rail and structural steel mill “Mechel” amounted to more than 900 million USD, “EVRAZ” spent on the reconstruction of its own rail production approximately 600 million USD.

3. Conclusions
The analysis of directions in improvement of the production technology of rails sections identified three major trends in the world’s steel industry: transition from the rolling of rail sections in the two-roll passes of stands “Duo” and “Trio” to the rolling with the use of continuous groups of universal mill stands; increase of the rails length up to 100 m and more; introduction of the technologies of differentiated rails hardening in different media instead of volumetric hardening. It is shown that the technological gap between the Russian metallurgical industry and the world leading rail manufactures of the last decades was closed in 2013–2014 when the new universal rolling mills at JSC “EVRAZ Consolidated West Siberian Metallurgical Plant” (“EVRAZ ZSMK”) and OJSC “Chelyabinsk Metallurgical Plant (company “Mechel”) were launched. Currently, these steel plants ensured a complete import substitution of long-length rails with increased wear resistance used in the construction of high-speed highways.

4. References
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