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Short report
Краткое сообщение

Anthology of rails produced by JSC EVRAZ United West Siberian Metallurgical Plant in the 21st century

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Abstract. JSC EVRAZ United West Siberian Metallurgical Plant is the main manufacturer of rails in the Russian Federation. The work traces the evolution of the plant's rail assortment over the past quarter century. A brief review of publications on modern concepts of the formation of structural and phase states of defective substructure and properties of volumetrically and differentially hardened pre-eutectoid, trans-eutectoid and bainite rails during production and subsequent long-term operation was performed. The service life of rails is determined by many factors: metal purity, structure, phase composition, operating conditions, heat treatment technology, etc. Special attention is paid to a new type of rail products – rails of the DT400IK category with increased wear resistance and contact endurance made of eutectoid steel, designed for use in difficult conditions. The paper considers the promising areas of rail assortment expansion.

Keywords: rails, volumetric quenching, differential quenching, structure, properties, operation

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Антология рельсов производства «ЕВРАЗ Объединенный Западно-Сибирский металлургический комбинат» XXI века

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Аннотация. АО «ЕВРАЗ Объединенный Западно-Сибирский металлургический комбинат» является основным производителем рельсов в Российской Федерации. В работе прослежена эволюция рельсового сортамента комбината за последнюю четверть века. Выполнен краткий обзор публикаций по современным представлениям формирования структурно-фазовых состояний, дефектной субструктуры и свойств объемно и дифференцированно закаленных доэвтектоидных, заэвтектоидных и бейнитных рельсов при производстве и последующей длительной эксплуатации. Срок службы рельсов определяют многие факторы: чистота металла, структура, фазовый состав, условия эксплуатации, технология темообработки и др. Особое внимание уделено новому виду рельсовой продукции – рельсам категории ДТ400ИК повышенной износостойкости и контактной выносливости из заэвтектоидной стали, предназначенных для эксплуатации в сложных условиях. Рассмотрены перспективные направления расширения рельсового сортамента.

Ключевые слова: рельсы, объемная закалка, дифференцированная закалка, структура, свойства, эксплуатация

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Currently, railways account for up to 85 % of global freight turnover and more than 50 % of passenger transportation. In recent years, there has been a significant increase in the intensity of railway transport operations and traffic load, which necessitates high service durability of rails. To address these challenges, technologies for volumetric and differential quenching of 100-meter rails have been implemented, with production in Russia commencing in 2013 [1]. The processes of formation and evolution of the structural and phase states, as well as the properties of rail surface layers during long-term operation, constitute a complex set of interrelated scientific and technical issues. The importance of research in this area lies both in the depth of understanding it provides of fundamental issues in physical metallurgy and heat treatment, and in its practical significance [2].

A review of the literature [3 – 5] shows that the service life of rails is influenced by a range of factors, including metal purity, structure, phase composition, operating conditions, and heat treatment technology. In modern high-speed railway systems, high contact pressures cause significant structural changes in the surface layers of rails, even after relatively low accumulated tonnage. These changes are characterized by abnormally high microhardness and the decomposition of cementite. Over prolonged periods of operation, various defects accumulate in the rails, triggering processes such as segregation, relaxation, homogenization, recrystallization, and phase transitions. These processes can lead to the deterioration of the rails' physical and mechanical properties, ultimately resulting in rail failure.

Research aimed at understanding the physical mechanisms of hardening and the development of structural and phase states in rails during long-term operation highlights that this remains one of the key challenges in the fields of physical metallurgy, heat treatment, and condensed matter physics.

In 2018, JSC EVRAZ United West Siberian Metallurgical Plant (EVRAZ ZSMK) launched the production of a new type of rails made from trans-eutectoid steel of the DT400IK category. These rails are characterized by enhanced wear resistance and contact endurance, specifically designed for use on straight railway sections at speeds of up to 200 km/h and on curved sections without restrictions on load intensity [6].

At EVRAZ ZSMK, considerable attention is devoted to researching the wear resistance of rail steel under abrasive conditions [7] and in rolling contact conditions using specialized equipment, including to meet the requirements of international customers. The influence of microstructure and chemical composition on tribological properties has been thoroughly studied while maintaining comparable levels of mechanical properties and hardness. Based on the results of these studies, a new generation of general-purpose rails with a higher hardness category – DT370 – has been developed, offering a combination of superior physical, mechanical, and performance characteristics.

The study presented in [8] examines the evolution of approaches to the formation of structure and properties in rails of various structural classes produced by EVRAZ ZSMK over the past 25 years, covering all stages from rolling and heat treatment to long-term operation. Using modern methods of physical metallurgy, particularly transmission electron microscopy, a detailed layer-by-layer analysis was conducted. This analysis identified quantitative parameters of the dislocation substructure, internal stress fields, and structural-phase states formed in the rail head along the central axis and gage corner after volumetric and differential quenching, as well as their evolution during long-term service. A comparative assessment of the tribological properties of rails after volumetric and differential quenching and extended operation was carried out. The physical mechanisms responsible for rail metal hardening during prolonged service were identified, along with their quantitative characteristics.

Another study focused on methods for improving the fatigue life of rails through magnetic and plasma hardening, as well as electron beam treatment. Resource-efficient technologies, along with heat treatment and rolling modes for EVRAZ ZSMK rail production, were analyzed. Additionally, studies on the kinetics of austenite transformation were conducted to optimize the chemical composition and heat treatment processes of rail steels, including for the production of butt-welded joints [9].

The production of rails from bainitic steel remains a relevant challenge. Studies of promising bainitic steels have demonstrated the advantages of rails made from these steels in terms of a comprehensive set of physical and mechanical properties compared to rails made from traditional pearlitic steel. Based on the results of computational modeling, a new R71 rail profile has been developed, featuring an increased mass per meter to support heavy-haul freight operations in the Russia's Eastern Railway Network. These new rails are designed to meet the growing demands of modern rail transport, including higher railway capacity, increased load intensity, and enhanced reliability of rail track superstructure components. The introduction of R71 rails marks an important step towards creating a reliable, low-maintenance railway track in Russia for heavy-haul applications. In collaboration with representatives from JSC Russian Railways (RZD), an acceptance commission was held, and technical specifications were developed and approved. Field tests at the experimental ring of Railway Research Institute (JSC VNIIZHT), along with the certification process for these rails, are scheduled for the third quarter of 2025 [10].

The plant manufactures various types of switch rails and continuously expands its product line. A certificate

has been issued for a new type of switch rail – OR65 of the NT320VS category. These special-purpose rails are designed with enhanced strength and are intended for use in the construction of track superstructures on high-speed and mixed-traffic railway lines.

Key areas of development include the rolling of 800-meter-long rail strings with differential hardening, as well as improving the mechanical properties of differentially heat-hardened rails through the addition of modifying elements, particularly rare-earth metals. These technological innovations are expected to make railway tracks significantly quieter and reduce maintenance costs.

As part of the Strategy for the Development of the Metallurgical Industry of the Russian Federation through 2030, approved by the Russian Government at the end of 2022, a key objective has been set: to develop and implement technology for producing differentially heat-hardened rail strings 800 meters in length. These rails are expected to maintain uniform properties along their entire length and support an accumulated traffic tonnage of 2.5 billion gross tons, along with rail fastenings designed to offer comparable durability. The development of these advanced rails is already underway at EVRAZ ZSMK, with heavy-duty rails likely to be used in the production of the 800-meter-long rail strings at the plant.

As railway infrastructure continues to develop and expand, the demand for rail products is steadily rising. With each passing year, the speed and weight of rolling stock increase, resulting in greater load intensity on railway networks. EVRAZ ZSMK's rail production is well-equipped to meet the growing demands of 21st-century rail transport.

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Contribution of the Authors / Вклад авторов

V. E. Gromov – conceptualization, analysis of literary data on the influence of various factors on rails service life.
S. V. Konovalov – analysis of researches on the mechanisms of metal strengthening of rails during long-term operation.
E. V. Polevoi – analysis of developments of JSC EVRAZ United West Siberian Metallurgical Plant rail production in the 21st century.

В. Е. Громов – общая концепция работы, анализ литературных данных по влиянию различных факторов на срок службы рельсов.
С. В. Коновалов – анализ работ по механизмам упрочнения металла рельсов при длительной эксплуатации.
Е. В. Полевой – анализ разработок ЕВРАЗ ЗСМК по производству рельсов в XXI веке.

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