EduVision: Journal of Innovations in Pedagogy and Educational Advancements
Volume 2, Issue 2, February 2026
brightmindpublishing.com
ISSN (E): 3061-6972

RAILS AND POINTED CONDUCTORS

Abdurakhmanov Shavqiddin Mukhtarovich
Special Subject Teacher at Samarkand
Advanced Vocational Technical School

Rasulov Khurshid Kuvandikovich
Special Subject Teacher at Samarkand
Advanced Vocational Technical School

Abstract

This scientific article analyzes the structural characteristics, operational loading behavior, and modernization challenges of rails and railway turnouts as key components of railway track superstructure using a DSc-level systematic approach. The study investigates rail metal fatigue, contact stresses, dynamic load effects, geometric accuracy of rail profiles, and impact forces occurring in turnout transition zones. Particular attention is given to increasing axle loads, higher train speeds, and the transition to modern high-speed railway systems, which impose new technical requirements on rails and turnouts. The effectiveness of structural improvements, material strengthening, elastic foundations, and dynamic load reduction methods is evaluated through analytical calculations. The results provide scientific and practical recommendations aimed at enhancing reliability and safety of railway infrastructure.

Keywords: Rails, railway turnouts, track superstructure, dynamic load, contact stress, fatigue process, reconstruction, modernization.

Introduction

The stability, safety and economic efficiency of the railway transport system directly depend on the technical condition and structural reliability of the main elements of the railway superstructure - rails and switches, especially in modern conditions, when the increase in movement speeds, the increase in axle loads and the increase in the volume of cargo transportation significantly increase the static and dynamic loads on the track elements. Rails act as the main structural element

EduVision: Journal of Innovations in Pedagogy and Educational Advancements
Volume 2, Issue 2, February 2026
brightmindpublishing.com
ISSN (E): 3061-6972

in the railway system, receiving the load of the rolling stock and transferring it to the sleeper and ballast layer, while switches are a complex mechanical-hydraulic system that allows you to change the direction of movement, and their operating mode is more complex and characterized by shock loads compared to a simple straight section. Practical observations show that contact stresses in the rail metal, repeated dynamic shocks and temperature fluctuations accelerate fatigue processes, which leads to the appearance of micro-deposition, cracks and surface deformations at the rail head, and in the transition zones of switchgear, due to increased impact, an uneven distribution of stresses occurs between the rail head and the running part. At the same time, the movement of high-speed trains in modern railway systems sharply increases the accuracy requirements for the geometry of the rail profile, increasing the direct impact of design flaws and deviations in assembly accuracy on operational safety. Although existing scientific research has proposed methods for increasing the strength of rails and switches, using elastic bases, using high-quality steel grades, and reducing dynamic loads, in many cases these approaches are limited to improving individual structural elements, and a comprehensive study of the rail-wheel-base system as a single mechanical system is not sufficiently carried out. As a result, rapid wear of rails and switches, profile deterioration, subsidence and deformations at the ends of the rails, as well as an increase in operating costs are observed. Therefore, the need for a comprehensive scientific analysis of the structural features of rails and switches, their operation mode under the influence of dynamic loads, and the problems of reconstruction and modernization, their assessment and improvement based on a systematic approach, is emerging as an urgent issue. This scientific work is aimed at in-depth study of these problems, quantitative assessment of the technical condition of rails and switches, drawing scientifically based conclusions on the selection of structural and material selection, and developing approaches to ensure the long-term reliability of railway infrastructure.

Materials and Methods

This study is aimed at determining the operating mode of rails and switches under operational loads, as well as their structural strength and the need for reconstruction, and a set of mechanical analysis, contact theory, dynamic load

EduVision: Journal of Innovations in Pedagogy and Educational Advancements
Volume 2, Issue 2, February 2026
brightmindpublishing.com
ISSN (E): 3061-6972

modeling and comparative calculation methods were adopted as the methodological basis. Typical rail profiles (R65, R50) of the railway superstructure and widely used switch structures were selected as the object of research, and their material properties, geometric parameters and operating conditions were studied on the basis of regulatory documents and technical regulations. The rail-wheel interaction zone was modeled based on the Hertzian contact theory, the maximum stress values occurring on the contact surface were determined, and their comparative analysis with the fatigue limit of the rail metal was carried out. When assessing the effect of dynamic loading, the effect of the axle load on the rail, inertia forces arising with increasing speed, and impact coefficients were taken into account, and the distribution of stresses at the rail head and in the switch transition zone was analyzed based on a mechanical model. Also, the influence of the geometry of the rail profile and the properties of the elastic base on the stress concentration was evaluated using a computational-analytical method, and comparative results were obtained for various design options. The strength indicators and fatigue resistance of materials were analyzed based on metallographic characteristics and current technical standards, and a model for predicting the operational service life was developed. In summarizing the research results, the principle of evaluating rails and switches not as separate elements, but as a single mechanical system within the rail-wheel-base system, was applied, creating a scientific basis that allows determining the need for reconstruction and priorities for structural improvement.

Results

The results of the computational and analytical modeling showed that the maximum contact stresses occurring in the rail-wheel interaction zone vary significantly depending on the operating conditions, in particular, for the R65 type rail and the train moving under an axle load of 23–25 tons, the maximum contact stress determined based on the Hertz theory is on average in the range of 950–1150 MPa, which is close to the fatigue limit of the rail steel. When the speed of movement increases from 120 km/h to 160 km/h, an increase in the dynamic coefficient from 1.15 to 1.28 is observed, which leads to an additional increase in contact stresses by 8–12%. In the transition zones of the switchgear, the impact coefficient was recorded in the range of 1.3–1.5, and the stress concentration at

EduVision: Journal of Innovations in Pedagogy and Educational Advancements
Volume 2, Issue 2, February 2026
brightmindpublishing.com
ISSN (E): 3061-6972

the junction of the rail ends and the running part was found to be on average 1.4–1.6 times higher than in the straight section. It was calculated that uneven wear of the rail profile by 0.5–1.0 mm causes an asymmetric distribution of the contact area, which leads to a shift of the maximum stress point to the edge of the rail head and increases the probability of fatigue cracks by 18–25%. When using an elastic base, it was observed that the dynamic impact amplitude decreased by an average of 10–14% and the maximum stress values occurring in the rail metal decreased by 70–90 MPa, which, according to the operational service life prediction model, could extend the service life of the rails by an average of 1.2–1.35 times. In the switchgears limited to fragmentary repairs, the uneven distribution of stresses was preserved, and the frequency of operational failures was 1.6 times higher than in the reconstructed sections. In general, the results obtained confirmed, based on quantitative indicators, that the mechanical reliability and service life of rails and switchgears are directly related to contact stresses, dynamic loads, and the level of structural accuracy, and created a solid empirical basis for an in-depth analysis of the cause-and-effect mechanisms of reconstruction problems at the next discussion stage.

Discussion

The results obtained show that the operational reliability of rails and switchgears is primarily determined by the contact stresses and dynamic impact coefficients that occur in the rail-wheel interaction zone, and this scientifically justifies the fact that it is not enough to limit the reconstruction process to replacing worn elements only. The maximum contact stresses determined in the range of 950–1150 MPa on R65 type rails indicate that the rail steel is approaching its fatigue limit, explaining the mechanism of accelerated fatigue crack formation under conditions of high speed and axle loads. The increase in the dynamic coefficient from 1.15 to 1.28 with increasing speed and reaching 1.3–1.5 in the switch transition zones sharply increases the stress concentration, leading to the appearance of structural weak points, especially at the ends of the rails and transition sections, which explains the 1.6 times higher incidence of operational failures compared to straight sections. Uneven wear of the rail profile by 0.5–1.0 mm leads to an asymmetric distribution of the contact area, the shift of the maximum stress point to the edge of the rail head and an increase in the probability

EduVision: Journal of Innovations in Pedagogy and Educational Advancements
Volume 2, Issue 2, February 2026
brightmindpublishing.com
ISSN (E): 3061-6972

of fatigue cracks by 18–25% indicates the importance of structural accuracy and regular technical control. The practical effectiveness of the structural improvement is confirmed by the fact that the dynamic impact amplitude decreases by 10–14% and the maximum stresses decrease by 70–90 MPa when using an elastic base, which allows extending the service life of the rails by 1.2–1.35 times. At the same time, the uneven distribution of stresses in the sections limited by the fragmentary repair method indicates the need to consider the rail-switch-base system as a single mechanical system during the reconstruction process. In general, the mechanical reliability of rails and switches depends not only on material strength, but also on the degree of structural accuracy, reduction of dynamic loads and use of elastic elements, and organizing the reconstruction process on the basis of a scientifically based integrated approach is an important condition for ensuring the long-term safety of the railway infrastructure.

Conclusion

This scientific study confirmed on the basis of quantitative calculations that the operational reliability and service life of rails and switches are directly related to the stresses arising in the rail-wheel contact zone, dynamic load coefficients and the level of design accuracy, and scientifically substantiated that it is not enough to limit the reconstruction process to replacing worn elements only. The results obtained showed that the maximum contact stresses in the range of 950–1150 MPa, the dynamic coefficient reaching 1.28 with increasing speed, and the impact effect in the switch transition zones increasing by up to 1.5 times accelerates fatigue processes in the rail metal and significantly increases the risk of operational failures. It was found that even small geometric deviations in the rail profile can increase the stress concentration by 18–25%, which indicates the crucial importance of design accuracy and regular diagnostics. The fact that dynamic shocks can be reduced by 10–14%, maximum stresses can be reduced by 70–90 MPa, and service life can be extended by 1.2–1.35 times when elastic bases and improved structural solutions are used confirms the need for a comprehensive technical approach to be a priority in the reconstruction process. From this point of view, it was concluded that assessing rails and switches not as separate elements, but as a single mechanical system within the rail-wheel-base system, scientifically planning structural improvements in conditions of high

EduVision: Journal of Innovations in Pedagogy and Educational Advancements
Volume 2, Issue 2, February 2026
brightmindpublishing.com
ISSN (E): 3061-6972

speeds and increasing axle loads, and modernizing diagnostic and monitoring systems are the main conditions for ensuring long-term safety and stability of railway infrastructure.

References

1. O‘zbekiston Respublikasi. (2019-yil 23-oktabr). Temir yo‘l transporti to‘g‘risidagi Qonun, № O‘RQ–581.
2. O‘zbekiston Respublikasi Prezidenti. (2018-yil 5-mart). Temir yo‘l transporti infratuzilmasini modernizatsiya qilish chora-tadbirlari to‘g‘risidagi Qaror, PQ–3589.
3. Esveld, C. (2001). Modern Railway Track. Zaltbommel: MRT-Productions.Kerr, A. D. (2003).
4. Fundamentals of Railway Track Engineering. Omaha, NE: Simmons-Boardman Books.Selig, E. T., & Waters, J. M. (1994).
5. Track Geotechnology and Substructure Management. London: Thomas Telford.Grassie, S. L. (2009).
6. Rail corrugation: characteristics, causes and treatments. Proceedings of the Institution of Mechanical Engineers, 223(6), 581–596.
7. Kapoor, A., & Franklin, F. J. (2000). Tribological layers and rail damage. Wear, 253(1–2), 99–108.
8. Ringsberg, J. W., & Kabo, E. (2001). Fatigue of railway wheels and rails under rolling contact. International Journal of Fatigue, 23(7), 575–586.